Discovery07 — The Black Swan Grid

900 hypotheses · 300 screened · 30 refined · 3 proofs

2 November 2026

Discovery07 — The Black Swan Grid

900 hypotheses, 300 screened, 30 refined, 3 taken to proof. Compiled 2 November 2026. Every entry is a proposition. **No experiment was performed.**

The idea

Black-swan hunting is not a search for likely things. It is a search for the small number of surprising things that happen to be true, and it only works if the search is wide, cheap to kill, and honest about its own base rate.

So the 900 are not 900 variations on a theme. They are generated by a grid: **30 operators × 30 domains**. An *operator* is a way of being strange — invert the artefact and make the signal; go to the limit nobody visits; break the device on purpose; follow a conserved quantity until the books do not balance; find a number that should not be universal. A *domain* is a field. Every operator is applied exactly once in every domain, so the grid is exhaustive in structure even where individual entries are wrong.

The expected yield is low. If one in a hundred of these is worth a week of someone's time, that is nine leads. If one in a thousand is a real discovery, that is one. The collection is designed so that all 900 can be killed cheaply and the survivors found fast.

The four tiers

Tier	What it is	Where
900	One claim, one mechanism, one kill test each. 30 per operator.	Part I (`grid/`)
300	Ten per operator, selected by a stated, reproducible rule, with survival tags describing testability rather than truth.	Part II (`screen/`)
30	Developed further: what survived screening, the mechanism, the decisive test, the refutation, and a status label.	Part III (`refined/`)
3	Derivations with numerical checks that regenerate every quoted number.	Part IV (`proofs/`)

The three proofs

1. **$T_2 \le 2T_1$ is universal — and the ratio is a spectrum meter.** I set out to show that non-Markovian noise lets a qubit escape the bound. The exact filter-function calculation refuted that: refocusing suppresses dephasing but not energy relaxation, so every sequence saturates at 2.000 and never crosses. The bound is stronger than I claimed. What survives is better: the free-induction ratio T_2^*/T_1 is a monotone map of the noise spectral index, calibrated here from 0.05 at $\beta = 0.25$ to 1.97 at $\beta = 2.5$.
2. **Bulk and surface photocurrent are separable by a 1/d law.** In a centrosymmetric film the bulk photovoltaic current vanishes by symmetry, so $J(d) = j_b + j_s/d$. The $1/d$ term is dimensional bookkeeping, not a model. A

100 nm film can read 200% above the bulk value, and a two-parameter fit over a thickness series recovers both terms with 1% uncertainty.

3. **The fluctuation–dissipation bound on oscillator coherence.** $\tau_\varphi \leq \hbar Q/(k_B T)$. At $Q = 10^6$ and $T = 20$ mK that is 382 μs at 100 kHz. Every optomechanics paper reports Q and T and a coherence; the bound turns three numbers into a one-line consistency check.

What is honest about this collection

- **Most of the 900 are wrong.** The grid is a search space, not a set of beliefs. The survival tags mark testability, not plausibility.
- **One hypothesis was refuted by its own proof attempt** (P1), and the refutation is kept next to the surviving result.
- **The screening rule is mechanical and stated**, so the 300 can be re-derived from the 900 without trusting the editor.
- **Nothing here is an observation.** There are no new data, no new spectra, no new images. The numbers are computed from stated models.
- **No prior Incoprea hypothesis was reused.** The 900 were checked against 6,007 titles from the existing corpus; the operators and the grid structure are new, and the few topic overlaps carry different mechanisms.

Where to start

1. **P2** if you want the most likely to be true and the cheapest to check: a thickness series and a two-parameter fit.
2. **P1** if you want the most surprising correction: the theorem is stronger than the folklore and the ratio is a free instrument.
3. **R04, R07, R12** in Part III for the three black-swan ideas with the best ratio of insight to cost.

Files

File	What it is
`Discovery07.pdf`	The complete document
`Discovery07.docx`	The same in Word
`grid/01…06-operators-*.md`	The 900, by operator
`screen/screened-300.md`	The 300, with survival tags
`refined/refined-30.md`	The 30
`proofs/PROOFS.md`, `proofs/D07_proofs.py`	The three proofs and the code
`data/grid900.csv`, `data/selected300.json`, `data/proofs.json`	Structured data
`METHODOLOGY.md`	The grid, the scoring rule, the limits
`CORRECTIONS.md`	What changed, what failed, what was refuted

Part I — The 900

900 hypotheses, each generated by applying one **operator** (a way of being strange) to one **domain**. The grid is 30 × 30, so every operator is applied exactly once in every field. No entry claims an observation; each states a claim, a mechanism, and the test that kills it.

Legend: `Bnnn` · *domain* — **claim**. *Mech:* mechanism. *Kill:* the observation that ends it.

Operator 1 — Inversion: the artefact is the signal

The measurement's rejected term carries more information than the term it was rejected from. Black-swan flavour: the thing you throw away is the instrument.

B001 · *condensed-matter* — Cryostat thermal drift is a phonon-transport signal, not noise. *Mech:* drift rate tracks the sample's thermal conductance to the bath at the 10^{-5} W/K level. *Kill:* drift rate independent of sample mounting conductance across a decade.

B002 · *soft-matter* — Wall slip in a rheometer is a slip-length measurement with 100 nm resolution. *Mech:* apparent viscosity deficit scales as the slip length over gap; reversing the gap separates slip from shear thinning. *Kill:* apparent slip independent of gap at fixed stress.

B003 · *electrochemistry* — The uncompensated resistance is a thermometer with microkelvin resolution. *Mech:* dR/dT of the electrolyte is 2%/K, so 1 $\mu\Omega$ in 10 Ω resolves 5 mK. *Kill:* R drift uncorrelated with an independent thermocouple at fixed current.

B004 · *catalysis* — Coke deposition is an active-site titration, not a deactivation nuisance. *Mech:* the coke formed per turnover is fixed by site geometry, so the coke-versus-time curve counts working sites. *Kill:* coke per converted molecule varying by more than 2× across a site-density series.

B005 · *photochemistry* — Photobleaching is a photon dosimeter with 1% absolute accuracy. *Mech:* bleaching quantum yield is fixed for a given dye-oxygen pair, so the bleach is an integral of absorbed photons. *Kill:* bleach per absorbed photon varying with intensity at fixed oxygen.

B006 · *ultrafast* — Pulse chirp is a direct measure of the medium's nonlinear refractive index. *Mech:* the chirp acquired is proportional to the B-integral, which is n_2 times intensity times length. *Kill:* extracted n_2 disagreeing with interferometric measurement by more than 20%.

B007 · *quantum-devices* — Readout crosstalk is a two-qubit coupling meter that beats spectroscopy. *Mech:* the crosstalk matrix element falls off as the inverse cube of detuning, so its tail measures the residual coupling at large detuning where spectroscopy is blind. *Kill:* crosstalk tail independent of detuning in the predicted power law.

B008 · *precision-metrology* — The servo error signal is a sub-nanometre displacement sensor. *Mech:* in lock, the error channel gain is calibrated by the feedback itself, so its noise floor sets displacement sensitivity without a separate interferometer. *Kill:* error-channel displacement disagreeing with the interferometer by more than its own noise.

B009 · *nuclear-particle* — Detector dead time is a precise flux monitor. *Mech:* the observed-to-true ratio is a known function of rate, so the dead time extracted from a rate sweep is a flux calibration. *Kill:* extracted dead time varying with source strength beyond counting statistics.

B010 · *astrophysics* — PSF anisotropy is a turbulence monitor with better time resolution than a differential image motion monitor. *Mech:* the ellipticity induced by the atmosphere responds to the same Cn^2 integral as scintillation but at higher frequency. *Kill:* ellipticity power spectrum uncorrelated with scintillation index above 1 Hz.

B011 · *planetary* — Coronagraph stray light is a map of the instrument's dust population. *Mech:* the scattered-light halo shape follows the dust size distribution's forward-scattering lobe. *Kill:* halo shape invariant after a controlled contamination event.

B012 · *geophysics* — Instrument tilt is a long-period seismometer that needs no feedback. *Mech:* a tilt step produces a displacement-equivalent signal at periods beyond the instrument's corner, and the step response identifies the tilt. *Kill:* tilt inferred from the step disagreeing with a co-located tiltmeter by more than 20%.

B013 · *atmosphere* — The radiosonde's pump lag is a ventilation measurement, not an error. *Mech:* lag time scales inversely with ascent-rate-dependent airflow, so the lag identifies the pump's effective flow. *Kill:* lag time independent of ascent rate over a 3× range.

B014 · *ocean-ice* — Biofouling on an optical sensor is a productivity record with daily resolution. *Mech:* fouling growth follows the same light-and-nutrient limitation as phytoplankton, so the fouling curve integrates local production. *Kill:* fouling growth uncorrelated with independent chlorophyll at fixed depth.

B015 · *hydrology-soil* — Rain-gauge evaporation loss is a latent-heat flux measurement. *Mech:* the loss rate is set by the same aerodynamic resistance as evapotranspiration, so the gauge is a miniature lysimeter. *Kill:* loss rate uncorrelated with eddy-covariance latent heat at the same site.

B016 · *microbiology* — Plate-edge evaporation is a humidity sensor array with 96 independent elements. *Mech:* edge wells lose volume faster; the evaporation profile is set by the plate's boundary-layer geometry, which tracks incubator airflow. *Kill:* evaporation profile invariant to incubator fan speed.

B017 · *plant-agriculture* — The porometer's leaf clamp is an embolism detector. *Mech:* clamping perturbs xylem tension; the recovery time constant lengthens sharply once cavitation begins. *Kill:* recovery time constant independent of the measured xylem pressure at the cavitation threshold.

B018 · *neuroscience* — Electrode impedance drift is a tissue-health monitor more sensitive than the neural signal. *Mech:* impedance rises with glial encapsulation before unit loss becomes visible. *Kill:* impedance drift uncorrelated with histological encapsulation in matched implants.

B019 · *immunology* — Assay background is a complement-activity measurement. *Mech:* the background from serum on an untreated plate is dominated by alternative-pathway deposition, which varies with donor. *Kill:* background independent of a complement-specific functional assay across donors.

B020 · *developmental-biology* — Embryo autofluorescence is a metabolic-state readout that predicts developmental rate. *Mech:* NAD(P)H fluorescence tracks the redox ratio, which sets the rate of divisions. *Kill:* autofluorescence at a fixed stage uncorrelated with time to the next division.

B021 · *ecology-evolution* — Detector false positives are a biodiversity signal, not a contamination. *Mech:* the false-positive spectrum contains environmental DNA from non-target taxa at low abundance, in proportion to their true abundance. *Kill:* false-positive composition invariant to site while true composition changes.

B022 · *medicine-diagnostics* — ECG baseline wander is a respiration monitor with better compliance than a belt. *Mech:* the wander is driven by thoracic impedance and electrode motion, both proportional to tidal volume. *Kill:* wander-derived

volume uncorrelated with spirometry across posture changes.

B023 · *pharmacology* — Tablet dissolution lag is a gastric-motility probe. *Mech:* the lag distribution in vivo is set by pyloric opening, which the in vitro lag cannot reproduce; the mismatch is the motility measurement. *Kill:* in vivo lag distribution matching in vitro across formulations.

B024 · *food-science* — Package condensation is a shelf-life integrator with a single number. *Mech:* cumulative condensation tracks the time-integral of temperature excursions through the dew-point crossing. *Kill:* condensation mass uncorrelated with measured vitamin loss across storage profiles.

B025 · *materials-failure* — Tribometer wear debris is a third-body rheology probe. *Mech:* debris-bed shear strength is measurable from the friction coefficient's velocity dependence, which no clean-surface model predicts. *Kill:* velocity dependence identical with and without debris trapping.

B026 · *structural-civil* — The strain gauge's thermal output is a solar-radiation monitor. *Mech:* the apparent strain of a gauge on a shaded versus sunlit member differs by the absorbed flux divided by the convective coefficient. *Kill:* apparent strain difference uncorrelated with pyranometer readings on the same member.

B027 · *energy-systems* — Calendar self-discharge is a separator-pore-quality assay. *Mech:* self-discharge is dominated by redox shuttling through pinholes, so the rate maps the pore-size tail rather than the bulk separator. *Kill:* self-discharge rate independent of measured pore-size tail across separators.

B028 · *manufacturing* — Machine-tool thermal drift is a spindle-preload meter. *Mech:* the drift's time constant is set by bearing preload through the friction-to-heat path, not by ambient temperature. *Kill:* drift time constant invariant to a controlled preload change.

B029 · *acoustics-vibration* — Room reverberation is a wall-impedance measurement. *Mech:* the decay curve's curvature at late times reflects the absorptive mismatch between surfaces, which a single reverberation time cannot express. *Kill:* late-time curvature unchanged when a known absorber is added.

B030 · *signal-information* — ADC clock jitter is a phase-noise measurement of the sample clock. *Mech:* the jitter-induced noise floor scales with input slew rate, so two-tone tests recover the jitter spectrum without a phase-noise analyser. *Kill:* recovered jitter spectrum disagreeing with a direct phase-noise measurement by more than 3 dB.

Operator 2 — Limit-taking: the extreme case everyone avoids

Every model has a corner nobody measures. Go there deliberately.

B031 · *condensed-matter* — At the lowest measurable temperature, Wiedemann–Franz fails in a way that reveals the charge-neutral channel. *Mech:* the electronic thermal conductivity saturates when impurity scattering dominates while the electrical conductivity keeps rising, so the Lorenz ratio must fall below the Sommerfeld value by a factor set by the screening length. *Kill:* Lorenz ratio staying within 5% of Sommerfeld down to 50 mK in a dirty metal.

B032 · *soft-matter* — At infinite dilution, colloidal diffusivity deviates from Stokes–Einstein because the solvent's own correlation length matters. *Mech:* for particles below 5 nm, the slip length at the particle surface makes D exceed Stokes–Einstein by 10–40%, and the excess scales with the solvent's structural correlation length. *Kill:* D matching Stokes–Einstein within 2% for a 2 nm tracer across three solvents of different correlation length.

B033 · *electrochemistry* — At zero supporting electrolyte, the transference number becomes directly measurable from the limiting current's transient. *Mech:* without excess salt, migration and diffusion decouple in time, and the current's early-time slope gives the transference number without tracer methods. *Kill:* transient-derived transference number disagreeing with concentration-cell measurement by more than 10%.

B034 · *catalysis* — At zero conversion, the measured rate constant is not the steady-state one; the difference is the coverage relaxation time. *Mech:* the catalyst starts from a bare surface, and the approach to steady coverage takes seconds, so a differential reactor at zero conversion measures a transient. *Kill:* zero-conversion rate unchanged when the catalyst is pre-equilibrated at reaction conditions.

B035 · *photochemistry* — At zero quencher, the residual quenching is the solvent's own radical yield. *Mech:* even purified solvent generates radicals at a yield set by its C–H bond strength, giving a floor to every quenching measurement. *Kill:* residual quenching varying with solvent deuteration of the same bond strength.

B036 · *ultrafast* — At zero delay, the pump–probe signal contains a coherent artefact that measures the pulse's absolute phase. *Mech:* the non-resonant response at zero delay is the convolution of the field with itself, which is phase-sensitive. *Kill:* zero-delay signal invariant to a known phase step applied by a shaper.

B037 · *quantum-devices* — At zero bias, a tunnel junction's current noise measures the electromagnetic environment's impedance. *Mech:* the zero-bias noise is set by the real part of the environment impedance at the junction's plasma frequency. *Kill:* zero-bias noise invariant when a known series impedance is inserted.

B038 · *precision-metrology* — At zero averaging time, the Allan variance is dominated by the interrogating oscillator, not the Clock under test. *Mech:* at τ below the servo bandwidth, the measured variance is the local oscillator's, so short-τ stability claims describe the wrong device. *Kill:* short-τ variance unchanged when the local oscillator is swapped for one with different noise.

B039 · *nuclear-particle* — At zero energy threshold, the detector's rate is set by its own radioactivity, and the spectrum's shape measures the contamination depth profile. *Mech:* alpha versus beta emitters have different self-absorption signatures in the detector housing. *Kill:* zero-threshold spectrum invariant after a controlled surface etch.

B040 · *astrophysics* — At zero metallicity, the initial mass function is measurably top-heavy, and the evidence is in the elemental abundance ratios of the oldest stars. *Mech:* without cooling metals, fragmentation is suppressed, shifting the IMF; the signature is an enhanced alpha/Fe at fixed [Fe/H] below -4. *Kill:* alpha/Fe at [Fe/H] < -4 consistent with the solar-metallicity IMF prediction.

B041 · *planetary* — At zero atmospheric pressure, a body's surface still has a measurable gas layer from regolith outgassing, and it controls the surface temperature. *Mech:* a 10^{-9} bar exosphere provides enough conduction to change the nightside temperature by several kelvin. *Kill:* nightside temperature matching a pure-radiation model to within 1 K.

B042 · *geophysics* — At zero effective stress, fault gouge still has measurable shear strength from van der Waals attraction. *Mech:* below the critical stress, strength becomes independent of normal load and scales with grain size. *Kill:* shear strength extrapolating to zero as normal stress goes to zero.

B043 · *atmosphere* — At zero wind shear, the boundary layer still generates turbulence from surface heterogeneity at a predictable scale. *Mech:* the heterogeneity length sets the overturning scale, so the turbulence intensity is set

by the surface mosaic, not by the shear. *Kill:* turbulence intensity independent of mosaic length at zero shear.

B044 · *ocean-ice* — At zero salinity, sea ice's permeability is set by the air fraction, and the permeability controls the heat flux more than the brine. *Mech:* gas bubbles block brine channels, so the permeability exponent changes at a critical air content. *Kill:* permeability independent of air content at zero salinity.

B045 · *hydrology-soil* — At zero hydraulic gradient, soil water still moves by thermal osmosis at a measurable rate. *Mech:* a 1 K/m gradient drives a flux comparable to a 10^{-4} hydraulic gradient. *Kill:* flux vanishing with the thermal gradient removed.

B046 · *microbiology* — At zero growth rate, bacteria maintain a measurable maintenance energy that sets the death rate. *Mech:* the maintenance coefficient is fixed per species, so the survival time under starvation scales with the initial ATP. *Kill:* survival time independent of initial ATP at fixed species.

B047 · *plant-agriculture* — At zero light, leaves maintain a measurable respiration that is set by the previous day's light integral. *Mech:* the respiration rate tracks the carbohydrate pool, which integrates the previous photoperiod. *Kill:* dark respiration independent of the previous light integral.

B048 · *neuroscience* — At zero spikes, neurons still consume oxygen at a rate set by synaptic vesicle cycling. *Mech:* the resting metabolism includes a substantial presynaptic component that scales with release probability. *Kill:* oxygen consumption independent of release-probability manipulations at zero firing.

B049 · *immunology* — At zero antigen, naive T cells still proliferate at a rate set by self-peptide affinity. *Mech:* tonic signalling from self-peptide–MHC sets a baseline division rate that varies between clones. *Kill:* baseline division rate independent of self-peptide affinity in TCR transgenic lines.

B050 · *developmental-biology* — At zero maternal RNA, the embryo's first divisions still proceed on a stored protein pool, and the timing reveals the pool size. *Mech:* the division schedule under maternal-RNA depletion is set by the inherited protein, so the delay measures the pool. *Kill:* division timing unchanged by doubling the inherited protein.

B051 · *ecology-evolution* — At zero mutation, adaptation still occurs through phenotypic plasticity at a rate that sets the evolution rate. *Mech:* plasticity exposes cryptic variation, so the adaptive rate is non-zero without mutation and scales with the environmental autocorrelation. *Kill:* adaptive rate vanishing when mutation is abolished, at high environmental autocorrelation.

B052 · *medicine-diagnostics* — At zero dose, a drug still produces a measurable effect through the excipient's own pharmacology. *Mech:* common excipients have measurable effects at the doses used in placebos. *Kill:* zero-dose arm indistinguishable from no-treatment arm on the primary endpoint.

B053 · *pharmacology* — At zero protein binding, the free fraction still differs from unity because of the assay's membrane. *Mech:* ultrafiltration membranes adsorb lipophilic compounds, so the "free" fraction is understated by an amount set by logP. *Kill:* free fraction independent of membrane material at fixed logP.

B054 · *food-science* — At zero water activity, lipid oxidation still proceeds through a surface-mediated pathway with a measurable rate. *Mech:* the oxidised surface layer is renewed by diffusion from the bulk, so the rate is set by the diffusion coefficient at the glass transition. *Kill:* oxidation rate vanishing below the glass transition.

B055 · *materials-failure* — At zero applied stress, a metal still accumulates damage at a rate set by residual stress, and the rate is measurable by acoustic emission. *Mech:* residual stress gradients drive dislocation motion, producing

emission at a rate that tracks the gradient. *Kill:* emission rate proportional to applied stress with zero intercept.

B056 · *structural-civil* — At zero traffic, a bridge still accumulates fatigue damage from thermal cycling at a rate set by the diurnal range. *Mech:* restrained thermal strain produces stress cycles of amplitude set by the restraint stiffness. *Kill:* damage accumulation independent of diurnal range across similar bridges.

B057 · *energy-systems* — At zero current, a battery still ages through a calendar pathway whose rate is set by the electrode's stored energy, not its voltage. *Mech:* the driving force for SEI growth is the chemical potential difference, which persists at open circuit. *Kill:* calendar aging independent of state of charge at fixed voltage.

B058 · *manufacturing* — At zero cutting speed, tool wear still proceeds by diffusion at a rate that sets the low-speed limit. *Mech:* the diffusion couple is temperature-controlled, so the wear rate at zero speed is the diffusion rate. *Kill:* wear rate vanishing at zero speed.

B059 · *acoustics-vibration* — At zero excitation, a structure still radiates sound from thermal vibration at a measurable level. *Mech:* the thermal displacement noise couples to the surrounding air, giving a radiometric noise floor. *Kill:* radiated noise floor vanishing when the structure is in vacuum.

B060 · *signal-information* — At zero bandwidth, a channel still transmits information through timing, at a rate set by the clock's stability. *Mech:* the timing channel's capacity is set by the Allan variance rather than the amplitude bandwidth. *Kill:* timing-channel capacity independent of clock stability.

Operator 3 — Cross-domain transplant

Borrow a mechanism that is routine in one field and unknown in another, and check whether the second field has been measuring it all along.

B061 · *soft-matter* ← *astrophysics* — Colloidal gels coarsen by the same Ostwald mechanism as interstellar dust, and the rate is set by the same Kelvin equation. *Mech:* the gel's pore curvature drives mass transfer, so coarsening should follow the dust-grain law with the surface energy replaced by the interfacial tension. *Kill:* coarsening exponent differing from the predicted 1/3 by more than 0.05 across a tenfold change in interfacial tension.

B062 · *electrochemistry* ← *semiconductor physics* — The electrode's double layer has a depletion-length analogue, and the capacitance minimum occurs at the point of zero charge in a way predicted by the Mott–Schottky relation. *Mech:* the space-charge layer in a lightly doped electrode adds a series capacitance with a voltage-dependent width. *Kill:* capacitance–voltage slope independent of doping across a decade.

B063 · *catalysis* ← *enzymology* — Supported catalysts show substrate inhibition, not just site blocking, and the inhibition constant is measurable from the rate maximum's position. *Mech:* two substrates binding the same site with negative cooperativity reproduce the enzymatic inhibition law. *Kill:* rate maximum position independent of substrate concentration across catalysts.

B064 · *photochemistry* ← *nuclear physics* — Photon echoes in molecular aggregates show a "magic angle" revival analogous to spin echoes, and the revival time measures the inhomogeneous width directly. *Mech:* the rephasing condition for a three-pulse sequence depends on the static disorder's symmetry. *Kill:* revival time independent of the disorder width.

B065 · *ultrafast* ← *seismology* — Femtosecond transients in solids obey a Gutenberg–Richter-like size distribution when the excitation is near a threshold. *Mech:* avalanche-like carrier multiplication produces a power-law distribution of transient amplitudes with a b-value set by the multiplication rate. *Kill:* amplitude distribution not power-law at the threshold fluence.

B066 · *quantum-devices* ← *optics* — Qubit decoherence has a visible "speckle" pattern in the frequency domain when the noise is a sum of discrete fluctuators. *Mech:* each TLS produces a Lorentzian at its own frequency, so the spectrum is a random sum with speckle statistics. *Kill:* spectrum smooth at the resolution needed to resolve individual fluctuators.

B067 · *precision-metrology* ← *radio astronomy* — Clock comparisons can be self-calibrated by closure quantities, removing the need for an absolute reference. *Mech:* the phase closure of a three-clock triangle removes each clock's offset, leaving the differential drift. *Kill:* closure-derived drift disagreeing with direct comparison by more than the closure noise.

B068 · *nuclear-particle* ← *particle cosmology* — Detector backgrounds have an Olbers-like integral: the summed contribution of distant radioactivity dominates the floor. *Mech:* the background scales with the enclosed mass and the square of distance, so a distant shield mass can dominate a near one. *Kill:* background scaling only with near-shield mass.

B069 · *astrophysics* ← *electrochemistry* — Accretion disc dead zones have a Warburg-like impedance, and the observed quasi-periodic oscillations are the electrochemical signature of ion diffusion. *Mech:* the ion–electron coupling in the disc's dead zone produces a diffusion impedance whose characteristic frequency scales as D/L^2. *Kill:* QPO frequency not scaling with the predicted diffusion time across discs.

B070 · *planetary* ← *tribology* — Lunar dust levitation is a triboelectric charging problem with a measurable charge-to-mass threshold identical to industrial powder handling. *Mech:* the threshold field for lofting is set by the particle's charge-to-mass ratio and the surface's work function difference. *Kill:* lofting threshold independent of the measured work function difference.

B071 · *geophysics* ← *materials science* — Fault gouge has a grain-boundary sliding law, and the seismic coupling coefficient is the same parameter as the creep exponent. *Mech:* the creep exponent n sets both the laboratory strain rate sensitivity and the fault's coupling. *Kill:* coupling coefficient independent of the measured n across faults.

B072 · *atmosphere* ← *combustion* — Cloud droplet activation has the same Damköhler competition as spray ignition, and the activation threshold is predictable from the same group. *Mech:* the competition between supersaturation supply and droplet growth is a Damköhler number, so the threshold is universal. *Kill:* activation threshold not collapsing onto a single Damköhler curve across aerosol types.

B073 · *ocean-ice* ← *metallurgy* — Sea-ice brine channels undergo Ostwald ripening with a rate set by the same interfacial energy, so the permeability decays predictably with age. *Mech:* the channel network coarsens as t^(1/3), and the permeability follows the cube of the channel radius. *Kill:* permeability decaying with a different exponent in first-year ice.

B074 · *hydrology-soil* ← *polymer physics* — Soil aggregates have a reptation-like relaxation, and infiltration curves show the reptation time. *Mech:* the polymer-like relaxation of the organic binder sets the aggregate's creep, which controls the pore collapse under wetting. *Kill:* infiltration time constant independent of binder molecular weight.

B075 · *microbiology* ← *granular physics* — Bacterial colonies jam at a critical density with the same exponents as granular jamming. *Mech:* the colony's crowding is a jamming transition, so the viscosity should diverge with the same exponent. *Kill:* viscosity divergence exponent differing from 2.5 by more than 0.3.

B076 · *plant-agriculture* ← *electrical engineering* — Xylem cavitation is an impedance spectroscopy problem, and the embolism can be located by its frequency signature. *Mech:* a gas-filled conduit has a different dielectric response from a water-filled one, so the embolism's position is recoverable from the spectrum. *Kill:* spectral signature unchanged when embolism is induced at a known position.

B077 · *neuroscience* ← *condensed matter* — Cortical avalanches have a Griffiths phase, not a critical point, and the Griffiths temperature is measurable from the avalanche rate's temperature dependence. *Mech:* disorder broadens the transition, producing power laws over a range of parameters. *Kill:* avalanche exponent independent of the perturbation strength.

B078 · *immunology* ← *ecology* — Antibody affinity maturation follows a species–area relationship, and the repertoire's diversity is predicted by the germinal centre's volume. *Mech:* the number of surviving clones scales with the centre's volume to a power set by the selection strength. *Kill:* clone diversity independent of germinal centre volume.

B079 · *developmental-biology* ← *fluid dynamics* — Left–right symmetry breaking is a peristaltic pumping problem, and the nodal flow's direction is set by the cilia's phase gradient. *Mech:* the flow is a metachronal wave, so its direction and magnitude are predicted by the phase gradient. *Kill:* flow reversal occurring without a phase-gradient reversal.

B080 · *ecology-evolution* ← *finance* — Extinction cascades have the same tail exponent as financial drawdowns because both are driven by the same branching process. *Mech:* the cascade size distribution has a power-law tail with exponent 3/2 when the branching ratio is near one. *Kill:* cascade tail exponent differing from 3/2 by more than 0.2 across independent food webs.

B081 · *medicine-diagnostics* ← *seismology* — Tumour stiffness maps can be inverted with seismic tomography, and the inversion's resolution limit is the wavelength, not the detector. *Mech:* the same diffraction limit applies, so resolution claims finer than half the shear wavelength are artefacts. *Kill:* a lesion resolved below the half-wavelength limit by any elastography method.

B082 · *pharmacology* ← *chemical engineering* — First-pass metabolism is a residence-time distribution problem, and the hepatic extraction is the same dimensionless group as a reactor's conversion. *Mech:* the extraction ratio is a Damköhler number in the liver's flow. *Kill:* extraction ratio not collapsing onto the group across species.

B083 · *food-science* ← *glaciology* — Ice cream's coarsening follows the same Ostwald ripening as glacier ice, and the shelf-life exponent is set by the same interfacial energy. *Mech:* ice crystal growth is diffusion-limited with a t^(1/3) law. *Kill:* crystal size growing with a different exponent at fixed temperature.

B084 · *materials-failure* ← *biology* — Fatigue crack growth has a "healing" analogue in metals at high temperature, and the healing rate is set by the same diffusion that sets creep. *Mech:* crack-tip sintering competes with growth, so the threshold stress intensity is temperature-dependent in a predictable way. *Kill:* threshold stress intensity independent of temperature at fixed diffusion coefficient.

B085 · *structural-civil* ← *geophysics* — Building resonance shifts are precursors of earthquakes, and the shift is predictable from the same strain sensitivity as a strainmeter. *Mech:* the building's frequency shift is proportional to the applied

strain divided by the structural stiffness. *Kill:* frequency shift uncorrelated with co-located strainmeter records.

B086 · *energy-systems* ← *neuroscience* — Battery management can use spike-timing-dependent plasticity rules, and the resulting charging protocol is optimal in a provable sense. *Mech:* the degradation is a history-dependent plasticity, so an STDP-like rule minimises it. *Kill:* STDP protocol performing worse than constant-current across three chemistries.

B087 · *manufacturing* ← *epidemiology* — Defect clustering on a wafer follows the same spatial reproduction number as an epidemic, and the clustering exponent predicts yield better than Poisson. *Mech:* the negative-binomial clustering parameter is the reproduction number. *Kill:* yield prediction no better than Poisson across process nodes.

B088 · *acoustics-vibration* ← *quantum mechanics* — Acoustic black holes have a Hawking-like temperature, and it is measurable as a thermal noise floor in the cavity. *Mech:* the analogue horizon's temperature scales with the flow gradient. *Kill:* noise temperature independent of the flow gradient.

B089 · *signal-information* ← *thermodynamics* — Compressed sensing has a Landauer cost, and the cost is measurable as heat in the reconstruction hardware. *Mech:* each bit erased in the optimiser dissipates kT ln2, so the reconstruction's heat output scales with the measurement count. *Kill:* heat output independent of the number of measurements.

B090 · *condensed-matter* ← *biology* — Phononic crystals can be evolved, and the evolutionary trajectory has a measurable "fitness landscape" ruggedness. *Mech:* the bandgap is a fitness function, so the landscape's ruggedness predicts the evolvability. *Kill:* landscape ruggedness uncorrelated with the achievable bandgap across runs.

Operator 4 — Conservation accounting

Follow a conserved quantity through a measurement and find where the books do not balance. The discrepancy is the discovery.

B091 · *condensed-matter* — The measured heat capacity of a thin film violates the Dulong–Petit sum rule by an amount that equals the substrate's contribution. *Mech:* the addenda correction assumes the substrate's heat capacity is known, but the film strains it, changing the substrate's phonon spectrum. *Kill:* addenda-corrected heat capacity agreeing with bulk across film thicknesses.

B092 · *soft-matter* — The measured yield stress of a suspension exceeds the stress the particles can transmit, and the excess is the solvent's viscoelasticity. *Mech:* the solvent's own relaxation contributes a stress that is not subtracted in the standard protocol. *Kill:* yield stress independent of solvent molecular weight at fixed particle loading.

B093 · *electrochemistry* — Coulometry in a flow cell does not conserve charge, and the missing charge is the parasitic current to the reference. *Mech:* the reference electrode draws a current through the electrolyte that is not in the cell's current path. *Kill:* charge balance closing when a guarded reference is used.

B094 · *catalysis* — The carbon balance in a partial-oxidation reactor does not close, and the missing carbon is deposited in a location that is catalytically active. *Mech:* the deposit sits in the pore mouth, where it changes the effective diffusivity. *Kill:* carbon balance closing when the deposit is mapped and counted.

B095 · *photochemistry* — Photon accounting in a photocatalytic reactor does not close, and the missing photons are absorbed by the reactor wall. *Mech:* wall absorption is a function of the reactor's reflectance, which changes with fouling.

Kill: photon balance closing with a reflectance-matched reactor.

B096 · *ultrafast* — Energy accounting in a pump–probe experiment does not close, and the missing energy is stored in a long-lived coherent mode. *Mech:* the mode's energy is invisible to the probe's spectral window but appears in the transient grating. *Kill:* energy balance closing when the grating signal is included.

B097 · *quantum-devices* — The qubit's measured relaxation does not account for all the energy leaving it, and the missing energy goes into a mechanical mode. *Mech:* the qubit's electromagnetic energy is partly converted to phonons, which are not measured in the standard T_1 experiment. *Kill:* T_1 unchanged when the mechanical mode is detuned.

B098 · *precision-metrology* — The clock's error budget does not sum to the measured instability, and the missing term is a correlation between two nominally independent systematics. *Mech:* the two terms share a temperature coefficient, so they add coherently rather than in quadrature. *Kill:* budget closing when the correlation is measured and included.

B099 · *nuclear-particle* — The missing energy in a detector is not neutrinos but a slow component with a measurable delay. *Mech:* the scintillator's slow component escapes the integration gate, shifting energy between channels. *Kill:* missing energy independent of the integration gate width.

B100 · *astrophysics* — The baryon budget of a galaxy cluster does not close, and the missing baryons are in a phase that is invisible to X-ray but visible to dispersion measures. *Mech:* the warm-hot phase has a low emission measure but a measurable dispersion. *Kill:* dispersion-measure estimate leaving the same deficit.

B101 · *planetary* — The angular momentum budget of a planetary atmosphere does not close, and the missing term is the surface torque. *Mech:* the surface torque is measurable from the wind's near-surface shear but is omitted in reanalyses. *Kill:* budget closing when surface torque is included.

B102 · *geophysics* — The seismic moment budget of a fault does not close, and the missing moment is aseismic slip with a specific depth signature. *Mech:* the aseismic fraction scales with the depth of the brittle–ductile transition. *Kill:* moment budget closing with only seismic events across faults of different transition depth.

B103 · *atmosphere* — The methane budget does not close, and the missing source has a measurable isotopic signature that distinguishes it from all known sources. *Mech:* the missing term must satisfy both the mass and the ^{13}C balance, which over-determines its signature. *Kill:* a source inventory that closes both balances without a new term.

B104 · *ocean-ice* — The ocean's heat budget does not close, and the missing term is geothermal flux through the seafloor. *Mech:* the flux is small globally but concentrated at ridges, where it drives measurable bottom-water anomalies. *Kill:* heat budget closing when ridge flux is excluded.

B105 · *hydrology-soil* — The catchment water balance does not close, and the missing term is deep percolation that bypasses the measurement depth. *Mech:* preferential flow carries water below the sensor in events, so the loss scales with event intensity. *Kill:* closure achieved with a deeper sensor array.

B106 · *microbiology* — The carbon balance of a microbial culture does not close, and the missing carbon is in a volatile species that the standard off-gas analysis misses. *Mech:* the volatile's production tracks the overflow metabolism. *Kill:* closure achieved with a full volatile scan.

B107 · *plant-agriculture* — The nitrogen budget of a field does not close, and the missing nitrogen is fixed by a non-symbiotic pathway. *Mech:* the pathway's rate is set by the soil's phosphorus status. *Kill:* budget closing when the non-symbiotic

rate is measured directly.

B108 · *neuroscience* — The brain's energy budget does not close, and the missing expenditure is in glial cycling rather than neuronal firing. *Mech:* glial glutamate cycling consumes a fixed fraction of the total that is independent of firing rate. *Kill:* budget closing when glial cycling is inhibited.

B109 · *immunology* — The cytokine budget of an infection does not close, and the missing cytokine is bound to a soluble receptor that the assay cannot detect. *Mech:* the soluble receptor's affinity determines the hidden fraction. *Kill:* free and total measurements closing the balance.

B110 · *developmental-biology* — The cell-number budget of a tissue does not close, and the missing cells are extruded and counted as debris. *Mech:* extrusion rates differ between genotypes, biasing the apparent proliferation. *Kill:* cell counts closing when extruded cells are recovered.

B111 · *ecology-evolution* — The energy budget of a food web does not close, and the missing flux is the microbial loop. *Mech:* the loop's contribution scales with dissolved organic carbon, which is rarely measured. *Kill:* budget closing without the microbial term.

B112 · *medicine-diagnostics* — The dose–response budget does not close, and the missing drug is in a tissue compartment that the plasma assay cannot see. *Mech:* the tissue's partition coefficient predicts the missing mass. *Kill:* mass balance closing with tissue measurement.

B113 · *pharmacology* — The clearance budget does not close, and the missing route is renal secretion that saturation hides. *Mech:* secretion saturates before filtration, so the apparent clearance falls with dose. *Kill:* clearance dose-independent across the therapeutic range.

B114 · *food-science* — The mass balance of a drying process does not close, and the missing water is bound water with a different activity. *Mech:* the bound fraction is set by the glass transition, so the closure error tracks the storage modulus. *Kill:* closure error independent of the glass transition.

B115 · *materials-failure* — The wear-volume budget does not close, and the missing volume is transferred to the counterface as a film. *Mech:* the transfer film's thickness is measurable by profilometry and scales with the contact pressure. *Kill:* volume balance closing when the transfer film is measured.

B116 · *structural-civil* — The damping budget of a building does not close, and the missing damping is radiation into the soil. *Mech:* soil radiation damping scales with the foundation's impedance. *Kill:* budget closing when soil impedance is included.

B117 · *energy-systems* — The lithium inventory of a cell does not close, and the missing lithium is in a plated layer whose location is set by the separator's tortuosity. *Mech:* plating occurs where the local current density exceeds the limiting value. *Kill:* inventory closing when plating is mapped.

B118 · *manufacturing* — The material balance of an additive process does not close, and the missing powder is vaporised in a size-dependent way. *Mech:* vaporisation scales with the particle's absorptivity divided by its mass, so fine particles are preferentially lost. *Kill:* loss independent of the powder's size distribution.

B119 · *acoustics-vibration* — The acoustic energy budget of a room does not close, and the missing energy is transmitted through the structure rather than the air. *Mech:* the structure-borne path dominates at low frequency. *Kill:* budget closing with airborne paths alone at low frequency.

B120 · *signal-information* — The information budget of a measurement does not close, and the missing information is in the timing of the samples rather than their values. *Mech:* the sampling times carry information that the amplitude quantiser discards. *Kill:* channel capacity unchanged when timing jitter is removed.

Operator 5 — Dimensionless coincidence

A number that should depend on everything turns out to be universal. Find the ones hiding in existing data.

B121 · *condensed-matter* — The ratio of thermal to electrical boundary resistance at a metal–insulator interface is a universal number. *Mech:* both are set by the same interfacial transmission, so the ratio reduces to the Lorenz number times a geometric factor. *Kill:* ratio varying by more than 20% across metal–insulator pairs.

B122 · *soft-matter* — The yield strain of soft gels is universal at 3%. *Mech:* yield occurs when the network's strand extension reaches its contour limit, a purely geometric criterion. *Kill:* yield strain varying systematically with crosslink density.

B123 · *electrochemistry* — The ratio of double-layer capacitance to bulk permittivity is a universal length of 0.3 nm across electrolytes. *Mech:* the double layer's thickness is set by the ion's hydrated radius, which is nearly constant for the alkali series. *Kill:* the ratio varying by more than 30% across electrolytes.

B124 · *catalysis* — The volcano's apex occurs at a universal binding energy of -0.87 eV per adsorbate bond, independent of the reactant. *Mech:* the apex is where the adsorption and desorption barriers cross, which is set by the bond energy alone. *Kill:* apex position varying by more than 0.2 eV across reaction families.

B125 · *photochemistry* — The Stokes shift of a fluorophore is a universal fraction of its emission energy. *Mech:* the reorganization energy scales with the emission energy through the same solvent coordinate. *Kill:* fraction varying by more than 30% across solvents at fixed fluorophore.

B126 · *ultrafast* — The ratio of the electron–phonon relaxation time to the Debye period is universal at 3. *Mech:* both scale with the same lattice anharmonicity. *Kill:* ratio varying with temperature by more than a factor of two.

B127 · *quantum-devices* — The ratio of T_2 to T_1 in superconducting qubits has a universal upper bound of 2. *Mech:* pure dephasing adds only to $1/T_2$, so $T_2 \leq 2T_1$ for any Markovian noise. *Kill:* a device with $T_2 > 2T_1$ without non-Markovian evidence.

B128 · *precision-metrology* — The ratio of the clock's servo bandwidth to its linewidth is universal at 1. *Mech:* the optimum servo bandwidth for a given linewidth is set by the discriminant's slope. *Kill:* an operating point with a ratio outside 0.5–2 that outperforms.

B129 · *nuclear-particle* — The ratio of the detector's energy resolution to its photoelectron yield is universal. *Mech:* both are set by the Poisson statistics of the light production. *Kill:* ratio varying across scintillators by more than 20%.

B130 · *astrophysics* — The ratio of the accretion disc's inner radius to the black hole's gravitational radius is a universal 6 for all masses. *Mech:* the innermost stable orbit is set by general relativity alone. *Kill:* a measured ratio systematically different from 6 in a well-determined system.

B131 · *planetary* — The ratio of a planet's magnetic moment to its angular momentum is universal across bodies with active dynamos. *Mech:* both are set by the same convective power. *Kill:* ratio varying by more than an order of magnitude across Earth, Jupiter, and Mercury.

B132 · *geophysics* — The ratio of the seismic to aseismic moment release is universal for faults of the same maturity. *Mech:* the ratio is set by the ratio of the nucleation length to the fault length. *Kill:* ratio varying with fault length at fixed maturity.

B133 · *atmosphere* — The ratio of lightning flash rate to convective available potential energy is universal across storms. *Mech:* both scale with the updraft's mass flux. *Kill:* ratio varying by more than a factor of three across storms of the same CAPE.

B134 · *ocean-ice* — The ratio of sea-ice permeability to its brine volume fraction is universal at 3×10^{-9} m². *Mech:* the pore network's geometry is set by the ice's crystal texture, which is similar across conditions. *Kill:* ratio varying by more than a factor of three across ice types.

B135 · *hydrology-soil* — The ratio of field capacity to wilting point is universal at 2.2 for mineral soils. *Mech:* both are set by the same pore-size distribution's moments. *Kill:* ratio varying systematically with clay mineralogy.

B136 · *microbiology* — The ratio of the cell's doubling time to its division protein's lifetime is universal at 1. *Mech:* division is triggered when the protein accumulates to a threshold, which sets the ratio. *Kill:* ratio varying with growth medium at fixed temperature.

B137 · *plant-agriculture* — The ratio of stomatal conductance to photosynthetic capacity is universal at 0.01 mol $\mathrm{m^{-2}\ s^{-1}}$ per μmol $\mathrm{m^{-2}\ s^{-1}}$. *Mech:* both are optimised to the same marginal water cost. *Kill:* ratio varying systematically with aridity.

B138 · *neuroscience* — The ratio of synaptic to axonal energy cost is universal at 3. *Mech:* both scale with the same ion fluxes. *Kill:* ratio varying across brain regions by more than a factor of two.

B139 · *immunology* — The ratio of antibody affinity to B-cell receptor affinity is universal at 10 after maturation. *Mech:* selection multiplies affinity by a fixed factor per round. *Kill:* ratio varying with antigen valency.

B140 · *developmental-biology* — The ratio of the embryo's cleavage period to its cytoplasmic volume is universal. *Mech:* the cell-cycle oscillator's period is set by the diffusion time of a cytoplasmic factor. *Kill:* ratio varying across species with the same volume.

B141 · *ecology-evolution* — The ratio of extinction rate to origination rate at equilibrium is universal at 1 across clades. *Mech:* the equilibrium is set by the diversity dependence of both rates. *Kill:* ratio systematically different from 1 in well-sampled clades.

B142 · *medicine-diagnostics* — The ratio of a biomarker's within-person to between-person variability is universal at 0.3 for homeostatic analytes. *Mech:* homeostatic control sets the within-person variance relative to the population's setpoint spread. *Kill:* ratio varying by more than a factor of three across analytes.

B143 · *pharmacology* — The ratio of a drug's tissue residence time to its plasma half-life is universal at 3 for lipophilic drugs. *Mech:* the tissue partition sets both through the same distribution volume. *Kill:* ratio varying with logP.

B144 · *food-science* — The ratio of a food's glass transition to its melting temperature is universal at 0.7. *Mech:* both are set by the same intermolecular potential. *Kill:* ratio varying with water content.

B145 · *materials-failure* — The ratio of a material's fatigue limit to its yield strength is universal at 0.35 for steels. *Mech:* both are set by the same dislocation pile-up length. *Kill:* ratio varying with inclusion content.

B146 · *structural-civil* — The ratio of a building's first-mode period to its height is universal at 0.1 s/m. *Mech:* the period is set by the stiffness-to-mass ratio, which is similar across structural systems. *Kill:* ratio varying by a factor of two across structural types.

B147 · *energy-systems* — The ratio of a cell's thermal runaway onset to its separator's melting point is universal at 1.3. *Mech:* runaway requires the separator to lose mechanical integrity, which occurs at a fixed fraction above its melting point. *Kill:* ratio varying across chemistries.

B148 · *manufacturing* — The ratio of a machined surface's roughness to its tool's edge radius is universal at 0.1. *Mech:* the roughness is set by the tool's cutting-edge geometry. *Kill:* ratio varying with cutting speed at fixed tool.

B149 · *acoustics-vibration* — The ratio of a room's Schroeder frequency to its reverberation time is universal. *Mech:* both are set by the modal overlap. *Kill:* ratio varying across room shapes.

B150 · *signal-information* — The ratio of a channel's capacity to its bandwidth is universal at 1.44 bits per hertz for a matched SNR of 0 dB. *Mech:* Shannon–Hartley at unit SNR. *Kill:* a channel exceeding the bound.

Discovery07 — The Black Swan Grid, operators 6–10

Operator 6 — Protocol archaeology

The number in the paper is a residue of a procedure that was inherited rather than chosen. Change the procedure and the number moves.

B151 · *condensed-matter* — The reported resistivity of a metal film is a record of its measurement current. *Mech:* Joule heating raises the film above the bath by an amount set by the lead conductance, and the temperature coefficient of resistance converts it into a current-dependent resistivity. *Kill:* resistivity independent of measuring current from 1 μA to 1 mA at fixed geometry.

B152 · *soft-matter* — The reported plateau modulus of a gel depends on the preshear history of the loading protocol, not on the gel. *Mech:* loading destroys a fraction of the network that reforms on a timescale longer than the standard protocol. *Kill:* plateau modulus independent of the loading rate across two decades.

B153 · *electrochemistry* — The reported exchange current density of an electrode is a record of its polishing grit. *Mech:* the grit sets the step density, which sets the active area in a way that cyclic voltammetry cannot normalise. *Kill:* exchange current density independent of grit after ECSA normalisation.

B154 · *catalysis* — The reported selectivity of a catalyst is a record of its calcination ramp rate. *Mech:* the ramp sets the particle size distribution, which sets the fraction of low-coordination sites. *Kill:* selectivity independent of ramp rate at fixed final temperature.

B155 · *photochemistry* — The reported fluorescence quantum yield is a record of the cuvette's path length. *Mech:* inner filtering is path-dependent, and the standard 1 cm cuvette is a choice, not a constant. *Kill:* quantum yield independent of path length after inner-filter correction.

B156 · *ultrafast* — The reported electron–phonon coupling constant is a record of the probe wavelength. *Mech:* the probe's penetration depth sets the volume that is averaged, and the coupling varies with depth through the film's morphology. *Kill:* coupling constant independent of probe wavelength across the transparent window.

B157 · *quantum-devices* — The reported coherence time is a record of the pulse-calibration routine. *Mech:* the calibration sequence leaves the qubit in a slightly different state, and the T_2 measured from that state differs from the equilibrium one. *Kill:* T_2 independent of the calibration sequence used before it.

B158 · *precision-metrology* — The reported clock stability is a record of the data-analysis window. *Mech:* the overlapping Allan deviation with a long window suppresses the initial drift, so the quoted stability depends on the chosen window. *Kill:* stability independent of the analysis window across a factor of four.

B159 · *nuclear-particle* — The reported energy resolution of a calorimeter is a record of its operating temperature's stability, not of its intrinsic resolution. *Mech:* the gain drifts with temperature, and the drift broadens the line in a way that looks like intrinsic resolution. *Kill:* resolution unchanged at tenfold better temperature stability.

B160 · *astrophysics* — The reported stellar metallicity is a record of the continuum normalisation window. *Mech:* the pseudo-continuum is defined by hand-chosen sidebands, and the choice sets the equivalent width. *Kill:* metallicity independent

of the sideband choice across analysts.

B161 · *planetary* — The reported surface age of a planetary body is a record of the crater-counting area. *Mech:* the counting area is chosen to avoid resurfacing, which biases the age young. *Kill:* age independent of the counting area across plausible choices.

B162 · *geophysics* — The reported earthquake magnitude is a record of the station's response deconvolution. *Mech:* the deconvolution band sets the peak amplitude, so the magnitude depends on the processing band. *Kill:* magnitude independent of the deconvolution band.

B163 · *atmosphere* — The reported aerosol optical depth is a record of the Langley calibration's site. *Mech:* the calibration's intercept absorbs the site's drift, which differs between mountains. *Kill:* optical depth independent of calibration site after reanalysis.

B164 · *ocean-ice* — The reported sea-ice thickness is a record of the snow-depth assumption. *Mech:* the freeboard conversion depends on the assumed snow load, which is rarely measured. *Kill:* thickness independent of snow assumption when snow is measured.

B165 · *hydrology-soil* — The reported soil moisture is a record of the probe's insertion depth. *Mech:* the probe averages over its sensitive volume, which is depth-dependent. *Kill:* moisture independent of insertion depth at a uniform profile.

B166 · *microbiology* — The reported minimum inhibitory concentration is a record of the inoculum preparation time. *Mech:* the inoculum's physiological state changes with the time since dilution. *Kill:* MIC independent of inoculum age across a four-hour range.

B167 · *plant-agriculture* — The reported crop yield is a record of the plot's edge rows. *Mech:* edge rows receive more light and have higher yield, and the number of discarded rows varies. *Kill:* yield independent of the discarded-row count.

B168 · *neuroscience* — The reported receptive field is a record of the stimulus set used to map it. *Mech:* the field is defined by the stimuli that drove the cell, and sparse sets systematically underestimate extent. *Kill:* field extent independent of stimulus density.

B169 · *immunology* — The reported titre is a record of the plate's incubation time. *Mech:* the assay's endpoint is defined by a colour threshold that shifts with incubation. *Kill:* titre independent of incubation time within the assay's tolerance.

B170 · *developmental-biology* — The reported developmental stage is a record of the staging series used. *Mech:* staging series differ between atlases, and the offset is a constant that enters every downstream comparison. *Kill:* stage assignment independent of the atlas used.

B171 · *ecology-evolution* — The reported species richness is a record of the sampling effort's stopping rule. *Mech:* collectors stop when the accumulation curve flattens, which terminates at different richness depending on the order of samples. *Kill:* richness independent of sample order.

B172 · *medicine-diagnostics* — The reported sensitivity of a diagnostic is a record of the spectrum of patients recruited. *Mech:* sensitivity depends on the disease severity distribution, which is a recruitment property. *Kill:* sensitivity stable across recruitment settings.

B173 · *pharmacology* — The reported half-life is a record of the sampling schedule's last time point. *Mech:* the terminal phase is defined by the last samples, and truncation shortens the fitted half-life. *Kill:* half-life stable when sampling is extended by two half-lives.

B174 · *food-science* — The reported shelf life is a record of the storage trial's temperature steps. *Mech:* the Arrhenius extrapolation depends on the step spacing, and the standard spacing is a convention. *Kill:* shelf life independent of step spacing at fixed total exposure.

B175 · *materials-failure* — The reported fatigue limit is a record of the staircase test's step size. *Mech:* the staircase converges to a quantile that depends on the step size. *Kill:* limit independent of step size across a factor of two.

B176 · *structural-civil* — The reported concrete strength is a record of the cube's curing humidity. *Mech:* the humidity sets the degree of hydration at the test age. *Kill:* strength independent of curing humidity at fixed age.

B177 · *energy-systems* — The reported capacity retention is a record of the formation cycle's rate. *Mech:* the formation cycle sets the SEI's morphology, which sets the subsequent fade. *Kill:* retention independent of formation rate.

B178 · *manufacturing* — The reported surface finish is a record of the stylus's skid. *Mech:* the skid filters the topography, suppressing wavelengths it cannot follow. *Kill:* roughness independent of skid length across a factor of three.

B179 · *acoustics-vibration* — The reported sound power level is a record of the reverberation room's diffuseness. *Mech:* the room's modal density at low frequency sets the measurement's bias. *Kill:* power level independent of room across two rooms of different volume.

B180 · *signal-information* — The reported bit error rate is a record of the error-counting window. *Mech:* the window's alignment with a periodic impairment sets the count. *Kill:* BER independent of window alignment.

Operator 7 — Negative-result resuscitation

A null result was published, filed, and forgotten. Re-read it as a positive measurement of something nobody was looking for.

B181 · *condensed-matter* — The null result on "no field-induced resistivity change" is a bound on the electron's electric dipole moment in a solid. *Mech:* the null sets a limit that is tighter than the molecular-beam limit for certain lattice symmetries. *Kill:* a re-derived limit weaker than the existing beam limit.

B182 · *soft-matter* — The null result on "no shear thickening at low concentration" is a measurement of the solvent's excluded volume. *Mech:* the onset concentration where thickening appears encodes the particle's hydrodynamic radius. *Kill:* onset concentration independent of the measured radius.

B183 · *electrochemistry* — The null result on "no oxygen evolution on the cathode" is a quantitative measurement of crossover. *Mech:* the detection limit of the null sets an upper bound that is tighter than the crossover measured by permeability. *Kill:* the bound weaker than the existing crossover measurement.

B184 · *catalysis* — The null result on "no activity without the promoter" is a measurement of the background rate's origin. *Mech:* the residual activity without the promoter is the reactor wall's contribution, which can be quantified. *Kill:* residual activity scaling with catalyst mass rather than wall area.

B185 · *photochemistry* — The null result on "no singlet oxygen in the absence of sensitiser" is a measurement of the solvent's triplet yield. *Mech:* the detection limit sets a bound on the solvent's own yield. *Kill:* the bound weaker than a direct measurement of the solvent's yield.

B186 · *ultrafast* — The null result on “no coherent phonon above 100 K” is a measurement of the electron–phonon coupling’s temperature dependence. *Mech:* the null’s upper bound defines the coupling at that temperature. *Kill:* the bound weaker than a later positive measurement.

B187 · *quantum-devices* — The null result on “no photon-assisted tunnelling” is a bound on the environment’s impedance at the drive frequency. *Mech:* the absence of a sideband sets an upper limit on the coupling. *Kill:* the bound weaker than the measured impedance.

B188 · *precision-metrology* — The null result on “no Lorentz violation” is a measurement of the apparatus’s orientation stability. *Mech:* the null’s noise floor is set by the platform’s tilt stability, which is otherwise unmeasured. *Kill:* the bound independent of the platform’s measured tilt noise.

B189 · *nuclear-particle* — The null result on “no neutrinoless double beta decay” is a measurement of the detector’s radon emanation rate. *Mech:* the background model’s dominant term is the emanation, which the null constrains. *Kill:* the bound weaker than an independent emanation measurement.

B190 · *astrophysics* — The null result on “no gamma-ray line from the Galactic centre” is a measurement of the instrument’s continuum background shape. *Mech:* the line’s absence constrains the background’s curvature at that energy. *Kill:* the background shape unconstrained by the null.

B191 · *planetary* — The null result on “no methane on Mars” is a measurement of the surface’s adsorption capacity. *Mech:* the detection limit sets the maximum that can be hidden by regolith adsorption. *Kill:* adsorption capacity measured to be far larger than the bound requires.

B192 · *geophysics* — The null result on “no precursory signal before earthquakes” is a measurement of the strain sensitivity of the network. *Mech:* the null sets the maximum permissible precursory strain, which the network’s noise floor defines. *Kill:* the bound weaker than the network’s measured strain noise.

B193 · *atmosphere* — The null result on “no trend in upper-tropospheric water vapour” is a measurement of the sonde’s contamination. *Mech:* the null’s uncertainty is dominated by the sensor’s dry bias, which it therefore constrains. *Kill:* the bound weaker than the known dry bias.

B194 · *ocean-ice* — The null result on “no glacial meltwater in the core” is a measurement of the core’s drilling disturbance. *Mech:* the absence constrains the disturbance’s magnitude. *Kill:* the bound weaker than the measured disturbance.

B195 · *hydrology-soil* — The null result on “no deep percolation at this site” is a measurement of the lysimeter’s collection efficiency. *Mech:* the null’s bound is set by the lysimeter’s capture, which is otherwise unknown. *Kill:* the bound weaker than a tracer-based capture measurement.

B196 · *microbiology* — The null result on “no growth on this carbon source” is a measurement of the medium’s contaminating carbon. *Mech:* the null’s detection limit is set by the agar’s residual carbon. *Kill:* the bound inconsistent with the measured agar carbon.

B197 · *plant-agriculture* — The null result on “no benefit from mycorrhizae at high phosphorus” is a measurement of the soil’s indigenous inoculum. *Mech:* the null is explained by colonisation by native fungi, which the trial’s design can quantify. *Kill:* uninoculated controls showing no colonisation.

B198 · *neuroscience* — The null result on “no effect of the lesion on behaviour” is a measurement of the lesion’s actual extent. *Mech:* the null bounds the functional contribution per unit lesioned volume. *Kill:* the bound weaker than the lesion’s measured extent.

B199 · *immunology* — The null result on “no antibody response to the antigen” is a measurement of the antigen’s endotoxin content. *Mech:* the null is explained by tolerance induced by endotoxin, quantifiable from the batch. *Kill:* no difference in endotoxin content between batches.

B200 · *developmental-biology* — The null result on “no effect of gene knockdown” is a measurement of the maternal protein deposit. *Mech:* the null bounds the protein’s perdurance, which the knockdown cannot remove. *Kill:* knockdown reducing the protein below the bound.

B201 · *ecology-evolution* — The null result on “no local adaptation” is a measurement of the gene flow rate. *Mech:* the null bounds the selection-migration balance. *Kill:* the bound inconsistent with measured dispersal.

B202 · *medicine-diagnostics* — The null result on “no benefit of screening” is a measurement of the overdiagnosis rate. *Mech:* the null bounds the benefit net of overdiagnosis. *Kill:* the bound inconsistent with measured overdiagnosis.

B203 · *pharmacology* — The null result on “no drug–drug interaction” is a measurement of the victim drug’s fraction metabolised by the inhibited pathway. *Mech:* the null bounds the fraction metabolised, which is otherwise inferred from in vitro data. *Kill:* the bound inconsistent with the in vitro fraction.

B204 · *food-science* — The null result on “no pathogen growth at this pH” is a measurement of the undissociated acid fraction. *Mech:* the null is set by the weak acid’s pKa, which the trial can therefore constrain. *Kill:* growth in a pH-matched control with a different acid.

B205 · *materials-failure* — The null result on “no corrosion in this environment” is a measurement of the alloy’s passivation potential. *Mech:* the null bounds the potential below which passivation fails. *Kill:* passivation potential measured below the bound.

B206 · *structural-civil* — The null result on “no settlement” is a measurement of the survey’s closure error. *Mech:* the null’s bound is set by the levelling precision. *Kill:* the bound weaker than the measured closure error.

B207 · *energy-systems* — The null result on “no plating at this rate” is a measurement of the cell’s pressure distribution. *Mech:* plating requires local compression, so the null bounds the pressure uniformity. *Kill:* pressure measurement showing non-uniformity below the bound.

B208 · *manufacturing* — The null result on “no porosity in this build” is a measurement of the CT scanner’s resolution. *Mech:* the null’s bound is set by the voxel size. *Kill:* the bound weaker than the voxel size.

B209 · *acoustics-vibration* — The null result on “no acoustic emission from the crack” is a measurement of the sensor’s coupling. *Mech:* the null bounds the emitted energy, and coupling sets the bound. *Kill:* the bound weaker than a calibration-source measurement.

B210 · *signal-information* — The null result on “no information leak from the channel” is a measurement of the receiver’s dynamic range. *Mech:* the null bounds the leak, and the range sets the bound. *Kill:* the bound weaker than the measured range.

Operator 8 — Scale collision

Two length or time scales that are assumed separated are actually close, and the coupling produces something neither scale predicts alone.

B211 · *condensed-matter* — The electron mean free path and the phonon wavelength in a thermoelectric are comparable, so the Wiedemann–Franz law fails by a factor that sets the maximum zT. *Mech:* when both lengths are similar, the electron–phonon coupling redistributes momentum and the Lorenz ratio drops. *Kill:* zT following the Wiedemann–Franz prediction across a mean-free-path series.

B212 · *soft-matter* — The particle radius and the polymer correlation length in a nanocomposite are comparable, so the viscosity's concentration dependence changes exponent. *Mech:* at that crossover the depletion layer's overlap changes from pairwise to collective. *Kill:* viscosity exponent constant across a radius series at fixed polymer length.

B213 · *electrochemistry* — The double-layer thickness and the pore radius in a nanoporous electrode are comparable, so the capacitance's voltage dependence changes sign. *Mech:* overlapping double layers remove the screening that normally increases capacitance with concentration. *Kill:* capacitance monotonic in concentration for a sub-2 nm pore material.

B214 · *catalysis* — The reactant's mean free path and the catalyst's pore diameter are comparable, so Knudsen diffusion changes the selectivity's order in pressure. *Mech:* Knudsen transport removes the pressure dependence of the collision rate. *Kill:* selectivity order in pressure unchanged at Knudsen number near 1.

B215 · *photochemistry* — The exciton's diffusion length and the film's grain size are comparable, so the quantum yield's thickness dependence has a maximum. *Mech:* at that crossover the exciton neither fully quenches at the surface nor fully separates in the bulk. *Kill:* yield monotonic in thickness for a grain-size series.

B216 · *ultrafast* — The electron–phonon equilibration time and the pulse duration are comparable, so the measured temperature is a function of the pulse's chirp. *Mech:* the chirp changes the instantaneous energy deposition rate, which competes with equilibration. *Kill:* extracted temperature independent of chirp at fixed fluence.

B217 · *quantum-devices* — The qubit's anharmonicity and its linewidth are comparable in a transmon near the sweet spot, so the leakage channel opens and mimics a coherence limit. *Mech:* the leakage transition frequency moves inside the linewidth, converting dephasing into relaxation. *Kill:* leakage rate independent of anharmonicity across a tunable-transmon series.

B218 · *precision-metrology* — The atomic coherence time and the interrogation pulse duration are comparable, so the clock's stability is set by the pulse's shape rather than by the atom. *Mech:* the Dick effect's magnitude depends on the pulse's duty cycle in a way that dominates at that ratio. *Kill:* stability unchanged when the pulse shape is optimised at fixed duration.

B219 · *nuclear-particle* — The detector's drift length and its electrode spacing are comparable, so charge collection becomes a function of the interaction depth and the energy resolution degrades in a depth-dependent way. *Mech:* the drift-length crossover produces a depth-dependent induction signal. *Kill:* resolution independent of interaction depth.

B220 · *astrophysics* — The accretion disc's scale height and the radiation's mean free path are comparable in the inner region, so the spectrum's shape is set by the photosphere's geometry rather than the disc's temperature. *Mech:* at that ratio the spectrum forms in a scattering-dominated atmosphere. *Kill:* spectral shape following a blackbody with the disc's effective temperature.

B221 · *planetary* — The diurnal thermal skin depth and the regolith's grain size are comparable on small bodies, so the thermal inertia's interpretation changes. *Mech:* the grain-scale and body-scale heat transport couple. *Kill:* thermal inertia independent of grain size.

B222 · *geophysics* — The earthquake's rupture length and the fault's damage-zone width are comparable for small events, so the stress drop becomes scale-dependent. *Mech:* at that ratio the rupture samples the damage zone's compliance. *Kill:* constant stress drop across the crossover.

B223 · *atmosphere* — The turbulent outer scale and the boundary-layer depth are comparable in shallow layers, so similarity theory fails and the flux-gradient relation changes. *Mech:* at that ratio the largest eddies are constrained by the layer's depth. *Kill:* flux-gradient relation holding across a shallowing series.

B224 · *ocean-ice* — The brine channel spacing and the thermal diffusion length are comparable during rapid cooling, so the ice's salinity profile is set by the cooling rate. *Mech:* the channel network cannot equilibrate, so salt is trapped in a rate-dependent fraction. *Kill:* salinity profile independent of cooling rate.

B225 · *hydrology-soil* — The rainfall's correlation length and the hillslope's length are comparable, so the runoff coefficient becomes scale-dependent. *Mech:* the storm's spatial structure determines whether the slope integrates or samples it. *Kill:* runoff coefficient independent of storm correlation length.

B226 · *microbiology* — The colony's height and the oxygen penetration depth are comparable, so the growth rate is set by the colony's aspect ratio. *Mech:* at that ratio the hypoxic core's volume fraction changes with morphology. *Kill:* growth rate independent of colony aspect ratio.

B227 · *plant-agriculture* — The leaf boundary layer and the stomatal spacing are comparable, so the transpiration rate depends on stomatal clustering rather than density. *Mech:* the overlapping boundary layers change the effective conductance per stoma. *Kill:* transpiration following stomatal density alone at both clusterings.

B228 · *neuroscience* — The synaptic cleft and the glutamate diffusion length are comparable, so transmitter spillover is set by the synapse's geometry rather than its release probability. *Mech:* at that ratio the cleft's width controls cross-talk between adjacent synapses. *Kill:* spillover independent of cleft width.

B229 · *immunology* — The antibody's reach and the lymph node's follicle size are comparable, so affinity selection's stringency depends on follicle geometry. *Mech:* at that ratio the antigen's availability per B cell is set by the follicle's surface-to-volume. *Kill:* selection stringency independent of follicle size.

B230 · *developmental-biology* — The morphogen's decay length and the tissue's size are comparable at a specific stage, so patterning becomes size-dependent. *Mech:* the pattern scales with the tissue only when the ratio is large. *Kill:* pattern length constant across a tissue-size series.

B231 · *ecology-evolution* — The dispersal distance and the habitat patch size are comparable, so the metapopulation's persistence has a maximum at an intermediate patch size. *Mech:* at that ratio dispersal neither rescues nor over-exploits patches. *Kill:* persistence monotonic in patch size across the ratio.

B232 · *medicine-diagnostics* — The nanoparticle's size and the tumour's vascular pore size are comparable, so delivery has a maximum at a specific diameter. *Mech:* at that ratio both extravasation and clearance compete. *Kill:* delivery monotonic in particle size across 10–200 nm.

B233 · *pharmacology* — The drug's diffusion depth and the biofilm's thickness are comparable, so the MIC depends on biofilm geometry rather than on the drug. *Mech:* penetration becomes the rate-limiting step at that ratio. *Kill:* MIC independent of biofilm thickness.

B234 · *food-science* — The ice crystal's size and the light's wavelength are comparable, so the food's appearance depends on the crystal distribution rather than the water content. *Mech:* Mie scattering at that ratio makes the appearance

sensitive to the crystal size's second moment. *Kill:* appearance independent of crystal size at fixed water content.

B235 · *materials-failure* — The crack-tip process zone and the grain size are comparable, so fracture toughness becomes a function of texture rather than of the grain boundary. *Mech:* at that ratio the crack samples multiple grains. *Kill:* toughness independent of texture at fixed grain size.

B236 · *structural-civil* — The soil's wavelength at the building's frequency and the foundation's width are comparable, so soil–structure interaction depends on the impedance contrast in a way that a Winkler model misses. *Mech:* at that ratio the foundation radiates rather than reflects. *Kill:* interaction independent of foundation width at fixed soil.

B237 · *energy-systems* — The electrode's particle size and the diffusion length at the operating rate are comparable, so the apparent capacity depends on the C-rate in a geometry-specific way. *Mech:* at that ratio the concentration profile is neither uniform nor fully developed. *Kill:* capacity–rate curve independent of particle size.

B238 · *manufacturing* — The melt pool's depth and the powder layer's thickness are comparable, so porosity depends on the layer thickness in a non-monotonic way. *Mech:* at that ratio the pool either keys into the previous layer or bridges it. *Kill:* porosity monotonic in layer thickness.

B239 · *acoustics-vibration* — The wavelength and the panel's thickness are comparable at coincidence, so the transmission loss has a dip whose depth depends on damping. *Mech:* at that ratio the panel radiates efficiently. *Kill:* dip depth independent of damping.

B240 · *signal-information* — The symbol period and the channel's delay spread are comparable, so the equaliser's performance depends on the delay profile's shape rather than its RMS. *Mech:* at that ratio the shape's higher moments matter. *Kill:* performance predicted by RMS delay spread alone.

Operator 9 — Symmetry and antisymmetry

Something that must vanish by symmetry does not, and the residual measures the symmetry-breaking term.

B241 · *condensed-matter* — A centrosymmetric crystal shows a measurable photovoltaic current from its surface alone, and the surface's symmetry breaking is quantifiable. *Mech:* the surface's dipole layer produces a current that scales with the film's thickness-to-surface ratio. *Kill:* current vanishing as 1/thickness at fixed surface.

B242 · *soft-matter* — An isotropic suspension shows a measurable normal-stress difference in steady shear, which isotropy forbids. *Mech:* the measurement's finite gap breaks the symmetry, and the residual scales with gap. *Kill:* normal-stress difference independent of gap.

B243 · *electrochemistry* — A symmetric redox couple shows a measurable rectification, which the Butler–Volmer symmetry forbids. *Mech:* the electrode's surface dipole breaks the symmetry, and the rectification scales with the dipole moment. *Kill:* rectification vanishing on a dipole-free (hydrogen-terminated) surface.

B244 · *catalysis* — An achiral catalyst produces a measurable enantiomeric excess, which symmetry forbids. *Mech:* the support's chiral morphology or a handedness in the crystal breaks the symmetry, and the excess scales with the support's enantiomeric surface fraction. *Kill:* excess independent of support handedness.

B245 · *photochemistry* — A racemic solution shows a measurable circular dichroism, which symmetry forbids. *Mech:* magnetic circular dichroism from the spectrometer's field breaks the symmetry. *Kill:* dichroism vanishing when the field is shielded.

B246 · *ultrafast* — An isotropic medium shows a measurable azimuthal dependence of its transient absorption, which symmetry forbids. *Mech:* the pump's beam profile breaks the symmetry, and the dependence scales with the beam's ellipticity. *Kill:* dependence vanishing with a circular pump.

B247 · *quantum-devices* — A flux-tunable qubit shows a measurable asymmetry about its sweet spot, which the design symmetry forbids. *Mech:* the junction's capacitance asymmetry produces a second-order term. *Kill:* asymmetry vanishing in a symmetric-junction device.

B248 · *precision-metrology* — A clock's frequency shift reverses sign with the apparatus's orientation in a way that Lorentz invariance forbids. *Mech:* the residual is a systematic from the magnetic shield's asymmetry, and it scales with the shield's tilt. *Kill:* shift vanishing when the shield is made symmetric.

B249 · *nuclear-particle* — A detector's response is asymmetric in energy about the calibration line, which the Gaussian model forbids. *Mech:* charge trapping produces a low-energy tail whose fraction is set by the trap density. *Kill:* symmetric line shape at low trap density.

B250 · *astrophysics* — A rotating galaxy's warped disc shows a measurable lopsidedness that the axisymmetric model forbids. *Mech:* the lopsidedness is a m=1 mode driven by the halo's asymmetry. *Kill:* lopsidedness independent of the halo's measured asymmetry.

B251 · *planetary* — A planet's magnetic field has a measurable quadrupole that the dipole model forbids. *Mech:* the quadrupole is generated by the dynamo's hemispheric asymmetry. *Kill:* quadrupole consistent with zero at the measured precision.

B252 · *geophysics* — A fault's friction is asymmetric with slip direction, which the rate-and-state model forbids. *Mech:* the gouge's fabric develops a preferred orientation. *Kill:* symmetric friction in both directions after shear.

B253 · *atmosphere* — A cyclone's outflow is asymmetric in a way that the gradient-wind balance forbids. *Mech:* the asymmetry is produced by the storm's translation, which breaks the symmetry. *Kill:* asymmetry independent of translation speed.

B254 · *ocean-ice* — Sea ice's permeability is anisotropic in a way that the random-pore model forbids. *Mech:* the crystal's preferred orientation produces a fabric. *Kill:* isotropy in ice with a measured random texture.

B255 · *hydrology-soil* — Infiltration is asymmetric with slope aspect in a way that the isotropic model forbids. *Mech:* the aspect controls solar loading and soil structure. *Kill:* symmetry restored after aspect-matched controls.

B256 · *microbiology* — A bacterium's motility is asymmetric fore–aft in a way that low-Reynolds swimming forbids. *Mech:* the flagellar bundle's polymorphism breaks the symmetry. *Kill:* fore–aft symmetry in a bundle-locked mutant.

B257 · *plant-agriculture* — A root system is asymmetric in a way that the isotropic foraging model forbids. *Mech:* the asymmetry tracks a nutrient gradient that is not measured. *Kill:* symmetry when the gradient is homogenised.

B258 · *neuroscience* — A neuron's dendritic integration is asymmetric in a way that the cable model forbids. *Mech:* the asymmetry is produced by ion-channel gradients along the dendrite. *Kill:* symmetry when the gradient is clamped.

B259 · *immunology* — Antibody binding is asymmetric between the two Fab arms in a way that the bivalent model forbids. *Mech:* the first binding event changes the second arm's affinity. *Kill:* symmetric binding in a monovalent construct.

B260 · *developmental-biology* — A tissue's growth is asymmetric in a way that the isotropic expansion model forbids. *Mech:* the asymmetry tracks the extracellular matrix's anisotropy. *Kill:* symmetry when the matrix is isotropic.

B261 · *ecology-evolution* — A species' range is asymmetric in a way that the diffusion model forbids. *Mech:* the asymmetry tracks the prevailing wind or current. *Kill:* symmetry when dispersal is experimentally equalised.

B262 · *medicine-diagnostics* — A biomarker's distribution is asymmetric in a way that the log-normal model forbids. *Mech:* the asymmetry is a mixture of two subpopulations. *Kill:* symmetry after mixture separation.

B263 · *pharmacology* — A drug's tissue distribution is asymmetric between left and right in a way that systemic perfusion forbids. *Mech:* the asymmetry is first-pass extraction by the lung. *Kill:* symmetry after intravenous dosing that bypasses the lung.

B264 · *food-science* — A food's texture is asymmetric between compression and tension in a way that the elastic model forbids. *Mech:* the asymmetry is produced by the cell wall's buckling in compression. *Kill:* symmetry in a cell-wall-free material.

B265 · *materials-failure* — A crack's growth is asymmetric between the two tips in a way that the symmetric specimen forbids. *Mech:* the asymmetry is produced by the specimen's residual stress gradient. *Kill:* symmetry in a stress-relieved specimen.

B266 · *structural-civil* — A building's response is asymmetric between the two horizontal directions in a way that the symmetric plan forbids. *Mech:* the asymmetry is produced by the soil's anisotropy. *Kill:* symmetry on isotropic soil.

B267 · *energy-systems* — A cell's impedance is asymmetric between charge and discharge in a way that linear response forbids. *Mech:* the asymmetry is the charge-transfer coefficient's non-ideality. *Kill:* symmetry in a symmetric couple.

B268 · *manufacturing* — A machined surface's texture is asymmetric in a way that the isotropic tool model forbids. *Mech:* the asymmetry is produced by the tool's wear-land. *Kill:* symmetry with a fresh tool.

B269 · *acoustics-vibration* — A room's impulse response is asymmetric in time in a way that the linear model forbids. *Mech:* the asymmetry is produced by the loudspeaker's nonlinearity. *Kill:* symmetry with a low-distortion source.

B270 · *signal-information* — A channel's error distribution is asymmetric in a way that the Gaussian model forbids. *Mech:* the asymmetry is produced by the quantiser's mid-tread versus mid-riser choice. *Kill:* symmetry with a symmetric quantiser.

Operator 10 — Sign reversal

An effect has the opposite sign to what the accepted mechanism requires. Either the mechanism is wrong or a second one dominates.

B271 · *condensed-matter* — The thermopower of a doped semiconductor changes sign at a temperature where the mobility's temperature dependence reverses. *Mech:* the sign is set by the dominant scattering mechanism, not the carrier type. *Kill:* sign change absent in a mobility-matched control.

B272 · *soft-matter* — A suspension's normal stress changes sign with shear rate. *Mech:* the sign is set by the competition between particle migration and shear-induced diffusion. *Kill:* sign constant across a rate decade.

B273 · *electrochemistry* — The electrode's potential shifts positively on illumination in a material with the expected negative photovoltage. *Mech:* the surface state's charging reverses the band bending. *Kill:* sign independent of surface treatment.

B274 · *catalysis* — A promoter that should increase activity decreases it at high coverage. *Mech:* the promoter blocks the site ensemble required by the rate-determining step. *Kill:* monotonic activity increase with promoter coverage.

B275 · *photochemistry* — Fluorescence intensity increases with temperature over a range where thermal quenching requires a decrease. *Mech:* the temperature releases a trapped exciton population. *Kill:* monotonic decrease in a trap-free sample.

B276 · *ultrafast* — The transient transmission increases where the excited-state absorption should decrease it. *Mech:* the probe's spectral position is on the anti-Stokes side, where band filling dominates. *Kill:* sign independent of probe detuning.

B277 · *quantum-devices* — The qubit's frequency shifts up with applied gate voltage where the Stark effect requires a downshift. *Mech:* the gate changes the junction's charging energy through the dielectric's thickness. *Kill:* shift direction independent of gate geometry.

B278 · *precision-metrology* — The clock's frequency shifts up with temperature where the cavity's expansion requires a downshift. *Mech:* the fibre path's index change dominates and has the opposite sign. *Kill:* sign independent of fibre length.

B279 · *nuclear-particle* — The detector's pulse height increases with bias where the field should improve collection and increase height. *Mech:* the increased bias raises the dark current, which compresses the amplifier's gain. *Kill:* monotonic height with bias at constant dark current.

B280 · *astrophysics* — A galaxy's rotation curve falls where the dark-matter halo requires it to be flat. *Mech:* the beam smearing at low inclination biases the outer velocities low. *Kill:* decline persisting at high inclination.

B281 · *planetary* — A polar deposit's brightness decreases with frost deposition where it should increase. *Mech:* the frost's grain size grows and the scattering moves from backward to forward. *Kill:* brightness monotonic with deposition.

B282 · *geophysics* — A fault's strength increases with pore pressure over a range where effective stress requires weakening. *Mech:* the pressure opens microcracks that increase the contact area before it reduces the effective stress. *Kill:* monotonic weakening across the full pressure range.

B283 · *atmosphere* — The aerosol's radiative forcing is positive at a wavelength where scattering requires negative. *Mech:* the absorbing fraction dominates at that wavelength because of the particle's size. *Kill:* forcing sign independent of size.

B284 · *ocean-ice* — The sea ice's albedo increases with melt pond fraction over a range where ponds require a decrease. *Mech:* the ponds expose white ice beneath a thin, bright refrozen layer. *Kill:* monotonic decrease across the pond fraction range.

B285 · *hydrology-soil* — The infiltration rate decreases with initial moisture over a range where it should increase. *Mech:* wetting closes the macropores by swelling the clay. *Kill:* monotonic increase in a non-swelling soil.

B286 · *microbiology* — The growth rate decreases with temperature over a range where Arrhenius requires an increase. *Mech:* the membrane's lipid order changes, reducing nutrient uptake. *Kill:* monotonic increase in a membrane-adapted strain.

B287 · *plant-agriculture* — The photosynthetic rate decreases with CO_2 over a range where it should increase. *Mech:* the stomatal closure reduces the transpiration-driven nutrient flux. *Kill:* monotonic increase in a fertilised soil.

B288 · *neuroscience* — The synaptic response decreases with release probability over a range where it should increase. *Mech:* the vesicle pool depletion dominates at high probability. *Kill:* monotonic increase at low stimulation rates.

B289 · *immunology* — The antibody titre decreases with antigen dose over a range where it should increase. *Mech:* high-dose tolerance is induced. *Kill:* monotonic increase across the whole range.

B290 · *developmental-biology* — The growth rate decreases with nutrient over a range where it should increase. *Mech:* the nutrient activates a growth suppressor above a threshold. *Kill:* monotonic increase in a suppressor mutant.

B291 · *ecology-evolution* — The diversity decreases with habitat area over a range where it should increase. *Mech:* the larger area supports a predator that excludes competitors. *Kill:* monotonic increase with predator removal.

B292 · *medicine-diagnostics* — The biomarker decreases with disease severity over a range where it should increase. *Mech:* the marker is consumed by the disease process above a threshold. *Kill:* monotonic increase across the severity range.

B293 · *pharmacology* — The drug's effect decreases with dose over a range where it should increase. *Mech:* the drug induces its own metabolism above a threshold. *Kill:* monotonic increase with a metabolism-resistant analogue.

B294 · *food-science* — The shelf life increases with storage temperature over a range where it should decrease. *Mech:* the higher temperature keeps the product glassy and suppresses diffusion. *Kill:* monotonic decrease across the temperature range.

B295 · *materials-failure* — The wear rate decreases with load over a range where it should increase. *Mech:* the higher load forms a protective tribofilm. *Kill:* monotonic increase without a tribofilm former.

B296 · *structural-civil* — The damping decreases with amplitude over a range where it should increase. *Mech:* the amplitude closes the cracks that provide the damping. *Kill:* monotonic increase in a precracked specimen.

B297 · *energy-systems* — The cell's resistance decreases with state of charge over a range where it should increase. *Mech:* the electrode's lattice expands and improves contact. *Kill:* monotonic increase in a rigid-框架 material.

B298 · *manufacturing* — The surface roughness decreases with feed rate over a range where it should increase. *Mech:* the higher feed rate moves the tool into a smoother wear regime. *Kill:* monotonic increase across the feed range.

B299 · *acoustics-vibration* — The transmission loss decreases with the partition's mass over a range where the mass law requires an increase. *Mech:* the added mass lowers a coincidence frequency into the band. *Kill:* monotonic increase across the band.

B300 · *signal-information* — The bit error rate decreases with noise over a range where it should increase. *Mech:* the noise dithers the quantiser and breaks up a deterministic error pattern. *Kill:* monotonic increase with a noise-free source.

Discovery07 — The Black Swan Grid, operators 11–15

Operator 11 — Threshold law

There is a sharp switch at a point nobody has located, and everything on both sides is misinterpreted as a smooth trend.

B301 · *condensed-matter* — A metal film's resistivity has a sharp kink at the thickness where the surface scattering length equals the grain size. *Mech:* below the kink the two scattering channels add in parallel; above it they add in series. *Kill:* smooth resistivity–thickness curve through the predicted crossover.

B302 · *soft-matter* — A colloidal gel has a sharp liquid–solid transition at a fixed number of bonds per particle, independent of chemistry. *Mech:* rigidity percolation requires an average coordination of 2.4. *Kill:* transition at coordination values varying by more than 0.3 across chemistries.

B303 · *electrochemistry* — Dendrite nucleation has a sharp threshold in the ratio of current density to the diffusion-limited current, at 0.8. *Mech:* above the threshold the depletion layer's instability growth rate exceeds the tip's stabilising surface tension. *Kill:* nucleation at ratios varying by more than 20% across electrolytes.

B304 · *catalysis* — Catalyst deactivation has a sharp onset at a coke loading that corresponds to one monolayer on the active phase. *Mech:* pore-mouth blocking becomes collective once the first monolayer is complete. *Kill:* deactivation gradual through the monolayer point.

B305 · *photochemistry* — Singlet fission has a sharp threshold in the excitation density where biexciton annihilation overtakes fission. *Mech:* the threshold is set by the ratio of the fission rate to the annihilation rate. *Kill:* quantum yield smooth through the predicted density.

B306 · *ultrafast* — Above a fluence threshold, the transient reflectivity's sign flips because the electron gas becomes degenerate. *Mech:* the Fermi level crosses the probe's transition energy at a computable carrier density. *Kill:* no sign flip up to the damage threshold.

B307 · *quantum-devices* — Above a critical photon number, a driven qubit's response becomes bistable, and the threshold is the duffing parameter. *Mech:* the Kerr nonlinearity balances the drive at a calculable amplitude. *Kill:* response monotonic through the predicted amplitude.

B308 · *precision-metrology* — Above a critical atom number, the clock's stability stops improving because of cavity pulling. *Mech:* the collective cooperativity exceeds one. *Kill:* stability improving as √N beyond the predicted number.

B309 · *nuclear-particle* — Above a critical event rate, the detector's dead time becomes nonlinear and the measured rate saturates at a calculable value. *Mech:* the paralysable model's maximum rate is $1/(e\tau)$. *Kill:* measured rate exceeding the paralysable maximum.

B310 · *astrophysics* — Above a critical accretion rate, the disc's spectrum switches from thin to slim in a sharp way. *Mech:* the transition occurs when the radiation pressure exceeds the gas pressure at the inner radius. *Kill:* smooth spectral evolution through the transition.

B311 · *planetary* — Above a critical obliquity, a planet's climate switches to a runaway state at a computable angle. *Mech:* the annual-mean insolation at the pole exceeds the threshold for ice-free conditions. *Kill:* no switch across the

predicted angle.

B312 · *geophysics* — Above a critical slip rate, friction drops sharply (the flash-weakening threshold). *Mech:* the contact junctions melt at a computable temperature. *Kill:* smooth friction–velocity curve through the predicted rate.

B313 · *atmosphere* — Above a critical aerosol loading, cloud droplet number saturates sharply and the indirect forcing stops scaling. *Mech:* the competition for water vapour limits activation. *Kill:* forcing continuing to scale with loading.

B314 · *ocean-ice* — Above a critical brine volume, sea ice becomes permeable in a sharp step at 5%. *Mech:* the pore network percolates at that fraction. *Kill:* permeability smooth through 5%.

B315 · *hydrology-soil* — Above a critical rainfall intensity, infiltration switches from matrix to preferential flow in a sharp step. *Mech:* the surface storage exceeds the matrix's intake at a computable intensity. *Kill:* smooth partition across intensity.

B316 · *microbiology* — Above a critical cell density, quorum sensing switches on sharply at a computable autoinducer concentration. *Mech:* the positive feedback's gain exceeds one at the threshold. *Kill:* graded response through the predicted concentration.

B317 · *plant-agriculture* — Above a critical vapour pressure deficit, stomata close sharply and photosynthesis collapses. *Mech:* the hydraulic supply cannot meet the transpiration demand at a computable deficit. *Kill:* gradual decline through the predicted deficit.

B318 · *neuroscience* — Above a critical firing rate, a neuron switches to a depolarisation block at a computable rate. *Mech:* the sodium channel's inactivation exceeds recovery. *Kill:* monotonic rate increase to saturation.

B319 · *immunology* — Above a critical antigen density, the immune response switches from tolerance to activation. *Mech:* the signalling threshold is crossed when the receptor's occupancy exceeds a fixed fraction. *Kill:* graded response through the predicted density.

B320 · *developmental-biology* — Above a critical morphogen concentration, the tissue switches fate sharply at a computable threshold. *Mech:* the bistable switch's saddle node is at the threshold. *Kill:* graded fate distribution through the threshold.

B321 · *ecology-evolution* — Above a critical dispersal rate, a metapopulation switches from persistent to synchronised collapse. *Mech:* the synchrony's gain exceeds the rescue rate. *Kill:* persistence monotonic in dispersal.

B322 · *medicine-diagnostics* — Above a critical tumour size, the biomarker's detectability switches on sharply. *Mech:* the shedding rate's vascular dependence changes at the angiogenic switch. *Kill:* detectability gradual through the predicted size.

B323 · *pharmacology* — Above a critical dose, the drug's clearance switches from first to zero order sharply. *Mech:* the metabolising enzyme saturates at a computable concentration. *Kill:* linear clearance through the predicted dose.

B324 · *food-science* — Above a critical water activity, a food switches from glassy to rubbery in a sharp step at the glass transition. *Mech:* the plasticisation crosses the transition at a computable activity. *Kill:* gradual change through the transition.

B325 · *materials-failure* — Above a critical stress intensity, crack growth switches from slow to fast in a sharp step. *Mech:* the crack-tip's process zone exceeds the grain size. *Kill:* smooth growth-rate curve through the threshold.

B326 · *structural-civil* — Above a critical amplitude, a structure switches from linear to nonlinear in a sharp step. *Mech:* the gaps in the connections close at a computable displacement. *Kill:* smooth response through the amplitude.

B327 · *energy-systems* — Above a critical charging rate, lithium plating switches on sharply at a computable overpotential. *Mech:* the surface concentration reaches zero at the threshold. *Kill:* plating gradual through the rate.

B328 · *manufacturing* — Above a critical laser power, the melt pool switches from conduction to keyhole mode sharply. *Mech:* the recoil pressure exceeds the surface tension at a computable power. *Kill:* porosity smooth through the power.

B329 · *acoustics-vibration* — Above a critical excitation level, a structure's damping switches from linear to amplitude-dependent sharply. *Mech:* the joints begin to slip at a computable amplitude. *Kill:* damping constant through the level.

B330 · *signal-information* — Above a critical SNR, a decoder switches from failure to success sharply (the threshold effect). *Mech:* the code's minimum distance is exceeded at the threshold. *Kill:* gradual BER improvement through the threshold.

Operator 12 — Memory and hysteresis

The system remembers something it is not supposed to remember. The memory's decay time is the measurement.

B331 · *condensed-matter* — A metal film remembers its deposition rate for weeks, and the memory is readable from its resistivity's annealing curve. *Mech:* the vacancy concentration from the deposition is frozen in and anneals with a rate set by the initial supersaturation. *Kill:* identical annealing curves for films deposited at different rates.

B332 · *soft-matter* — A colloidal glass remembers the shear direction for hours, and the memory is readable from its yielding. *Mech:* the residual stress's anisotropy decays with the structural relaxation time. *Kill:* isotropic yielding immediately after shear.

B333 · *electrochemistry* — An electrode remembers its last potential for minutes, and the memory sets the apparent exchange current. *Mech:* the oxide's thickness relaxes with a time constant of minutes. *Kill:* exchange current independent of the prior potential's hold time.

B334 · *catalysis* — A catalyst remembers the reactant's partial pressure for hours, and the memory sets the apparent order. *Mech:* the surface coverage's relaxation is slow at low temperature. *Kill:* order independent of the pre-treatment pressure.

B335 · *photochemistry* — A fluorophore remembers its excitation intensity for seconds, and the memory sets the measured lifetime. *Mech:* the triplet population's relaxation is slow. *Kill:* lifetime independent of the prior excitation.

B336 · *ultrafast* — A sample remembers the previous pump pulse for nanoseconds, and the memory sets the measured relaxation. *Mech:* the accumulated heating relaxes slowly. *Kill:* relaxation independent of the repetition rate.

B337 · *quantum-devices* — A qubit remembers its last measurement for milliseconds, and the memory sets the next gate's fidelity. *Mech:* the measurement's backaction populates a long-lived state. *Kill:* fidelity independent of the preceding measurement.

B338 · *precision-metrology* — A clock remembers its transport for hours, and the memory sets the frequency offset. *Mech:* the thermal and mechanical relaxation of the cavity. *Kill:* offset independent of the transport history.

B339 · *nuclear-particle* — A detector remembers its dose for days, and the memory sets the energy scale. *Mech:* the radiation damage anneals slowly at room temperature. *Kill:* energy scale independent of accumulated dose.

B340 · *astrophysics* — A galaxy remembers its merger for gigayears, and the memory sets its present morphology. *Mech:* the phase-space spiral persists long after the merger. *Kill:* no phase-space structure in post-merger analogues.

B341 · *planetary* — A planet remembers its last ice age in its crustal stress, and the memory sets present-day seismicity. *Mech:* the glacial unloading's relaxation continues for millennia. *Kill:* seismicity independent of the unloading history.

B342 · *geophysics* — A fault remembers its last large earthquake for centuries, and the memory sets the next event's size. *Mech:* the stress heterogeneity from the previous rupture persists. *Kill:* event sizes independent of the previous event's extent.

B343 · *atmosphere* — The atmosphere remembers a volcanic eruption for years, and the memory sets the aerosol's size distribution. *Mech:* the stratospheric residence time is set by the particle's fall speed. *Kill:* size distribution independent of the eruption's age.

B344 · *ocean-ice* — Sea ice remembers its formation rate for a season, and the memory sets its permeability. *Mech:* the brine channel's geometry is set by the freezing rate. *Kill:* permeability independent of the formation rate.

B345 · *hydrology-soil* — A soil remembers its wetting history for weeks, and the memory sets its contact angle. *Mech:* the hydrophobic coating's conformation relaxes slowly. *Kill:* contact angle independent of the wetting history.

B346 · *microbiology* — A bacterial population remembers a stress for generations, and the memory sets its growth lag. *Mech:* the persister fraction's decay sets the lag. *Kill:* lag independent of the prior stress.

B347 · *plant-agriculture* — A plant remembers a drought for a season, and the memory sets its stomatal conductance. *Mech:* the hydraulic conductance's recovery is incomplete. *Kill:* conductance independent of the drought history.

B348 · *neuroscience* — A synapse remembers a stimulation pattern for hours, and the memory sets its release probability. *Mech:* the vesicle pool's refilling is slow. *Kill:* release probability independent of the prior pattern.

B349 · *immunology* — An immune cell remembers a cytokine exposure for days, and the memory sets its response threshold. *Mech:* the receptor's expression is epigenetically maintained. *Kill:* threshold independent of the prior exposure.

B350 · *developmental-biology* — A cell remembers its position for generations, and the memory sets its fate. *Mech:* the epigenetic mark's inheritance is stable. *Kill:* fate independent of the prior position.

B351 · *ecology-evolution* — An ecosystem remembers a disturbance for decades, and the memory sets its resilience. *Mech:* the seed bank's composition persists. *Kill:* resilience independent of the disturbance history.

B352 · *medicine-diagnostics* — A patient remembers an infection for years, and the memory sets the biomarker baseline. *Mech:* the immune imprint persists. *Kill:* baseline independent of the infection history.

B353 · *pharmacology* — A tissue remembers a drug exposure for weeks, and the memory sets the next dose's clearance. *Mech:* the enzyme induction decays slowly. *Kill:* clearance independent of the prior exposure.

B354 · *food-science* — A food remembers a temperature excursion, and the memory sets its texture. *Mech:* the ice crystal's size distribution is history-dependent. *Kill:* texture independent of the excursion.

B355 · *materials-failure* — A metal remembers an overload, and the memory sets its fatigue life. *Mech:* the overload's residual stress retards subsequent crack growth. *Kill:* fatigue life independent of the overload.

B356 · *structural-civil* — A bridge remembers an earthquake, and the memory sets its stiffness. *Mech:* the cracked connections' stiffness is history-dependent. *Kill:* stiffness independent of the seismic history.

B357 · *energy-systems* — A cell remembers a fast charge, and the memory sets its subsequent plating risk. *Mech:* the SEI's morphology is set by the fast-charge history. *Kill:* plating risk independent of the prior fast charge.

B358 · *manufacturing* — A tool remembers a hard spot, and the memory sets its wear rate. *Mech:* the chipping from the hard spot propagates. *Kill:* wear rate independent of the prior hard spot.

B359 · *acoustics-vibration* — A room remembers a temperature change, and the memory sets its reverberation. *Mech:* the air's absorption depends on humidity, which lags the temperature. *Kill:* reverberation independent of the humidity history.

B360 · *signal-information* — A channel remembers a burst of errors, and the memory sets the next burst's probability. *Mech:* the error bursts are clustered by the fading. *Kill:* burst probability independent of the prior burst.

Operator 13 — Crowding and interference

Two things that should not interact do, because the measurement puts them in the same place at the same time.

B361 · *condensed-matter* — Two adjacent thermocouples on a chip interfere through the substrate's thermal spreading, and the interference sets the apparent ZT. *Mech:* the heat from one junction raises the other's cold side by an amount set by the substrate's spreading resistance. *Kill:* ZT independent of junction spacing.

B362 · *soft-matter* — Two particles in an optical trap interfere hydrodynamically at separations ten times their radius. *Mech:* the Oseen tensor's long range. *Kill:* independence at separations beyond 10 radii.

B363 · *electrochemistry* — Two electrodes in the same cell interfere through the electrolyte's potential field, and the interference sets the apparent current efficiency. *Mech:* the current's distribution is set by the cell's geometry, not the electrode's area. *Kill:* efficiency independent of electrode spacing.

B364 · *catalysis* — Two catalyst beds in series interfere through the intermediate's adsorption, and the interference sets the apparent selectivity. *Mech:* the intermediate desorbs and re-adsorbs downstream. *Kill:* selectivity additive across beds.

B365 · *photochemistry* — Two fluorophores in the same cuvette interfere through inner filtering and radiative transfer, and the interference sets the quantum yield. *Mech:* the emission of one excites the other. *Kill:* yield additive across concentrations.

B366 · *ultrafast* — Two pump beams interfere through the sample's accumulated heat, and the interference sets the measured relaxation. *Mech:* the thermal grating's decay is slower than the electronic one. *Kill:* relaxation independent of the pump's spatial pattern.

B367 · *quantum-devices* — Two qubits on the same chip interfere through the substrate's phonon bath, and the interference sets the pair's coherence. *Mech:* the shared bath correlates the noise. *Kill:* pair coherence equal to the product of singles at all separations.

B368 · *precision-metrology* — Two clocks in the same laboratory interfere through the shared local oscillator, and the interference sets the measured stability. *Mech:* the common oscillator's noise cancels in the difference but not in the individual. *Kill:* stability independent of oscillator sharing.

B369 · *nuclear-particle* — Two detectors in the same shield interfere through the shared radon, and the interference sets the coincidence background. *Mech:* the radon's progeny deposit on both. *Kill:* coincidence rate scaling with single rate squared.

B370 · *astrophysics* — Two stars in the same field interfere through the telescope's scattered light, and the interference sets the faint companion's photometry. *Mech:* the halo's profile is set by the primary, not the background. *Kill:* companion photometry independent of separation.

B371 · *planetary* — Two craters interfere through the ejecta's blanketing, and the interference sets the age. *Mech:* the younger crater's ejecta covers the older's. *Kill:* age independent of the neighbour's proximity.

B372 · *geophysics* — Two faults interfere through the shared stress field, and the interference sets the recurrence. *Mech:* the Coulomb stress transfer advances or delays the neighbour. *Kill:* recurrence independent of the neighbour's events.

B373 · *atmosphere* — Two aerosol sources interfere through the shared oxidant budget, and the interference sets the secondary aerosol's yield. *Mech:* the oxidant is consumed by both. *Kill:* yield additive across sources.

B374 · *ocean-ice* — Two ice floes interfere through the shared snow, and the interference sets the thickness retrieval. *Mech:* the snow's redistribution is set by the floe's size. *Kill:* retrieval independent of floe size.

B375 · *hydrology-soil* — Two rain gauges interfere through the shared wind field, and the interference sets the undercatch. *Mech:* the upstream gauge's wake reduces the downstream one's catch. *Kill:* undercatch independent of the upstream gauge.

B376 · *microbiology* — Two colonies interfere through the shared nutrient, and the interference sets the growth rate. *Mech:* the depletion zone's overlap. *Kill:* growth rate independent of neighbour distance.

B377 · *plant-agriculture* — Two plants interfere through the shared root zone, and the interference sets the apparent water use. *Mech:* the hydraulic redistribution between roots. *Kill:* water use additive across plants.

B378 · *neuroscience* — Two electrodes interfere through the shared reference, and the interference sets the local field's amplitude. *Mech:* the reference's impedance is common. *Kill:* amplitude independent of the reference's position.

B379 · *immunology* — Two antibodies interfere through the shared epitope, and the interference sets the apparent affinity. *Mech:* the competition reduces the bound fraction. *Kill:* affinity additive across antibodies.

B380 · *developmental-biology* — Two adjacent cells interfere through the shared morphogen, and the interference sets the fate boundary. *Mech:* the morphogen's local depletion. *Kill:* boundary independent of the neighbour's fate.

B381 · *ecology-evolution* — Two species interfere through the shared predator, and the interference sets the apparent competition. *Mech:* the predator's numerical response. *Kill:* coexistence independent of the predator.

B382 · *medicine-diagnostics* — Two analytes interfere through the shared antibody, and the interference sets the false positive. *Mech:* the cross-reactivity's affinity. *Kill:* false positive independent of the cross-reactant's concentration.

B383 · *pharmacology* — Two drugs interfere through the shared transporter, and the interference sets the apparent clearance. *Mech:* the competition for the transporter. *Kill:* clearance additive across drugs.

B384 · *food-science* — Two ingredients interfere through the shared water, and the interference sets the texture. *Mech:* the water's partitioning between phases. *Kill:* texture additive across ingredients.

B385 · *materials-failure* — Two cracks interfere through the shared stress, and the interference sets the growth rate. *Mech:* the stress shadow's overlap. *Kill:* growth rate additive across cracks.

B386 · *structural-civil* — Two buildings interfere through the shared soil, and the interference sets the settlement. *Mech:* the stress bulbs overlap. *Kill:* settlement additive across buildings.

B387 · *energy-systems* — Two cells in a pack interfere through the shared thermal path, and the interference sets the aging rate. *Mech:* the neighbour's heat sets the cell's temperature. *Kill:* aging rate independent of the neighbour's load.

B388 · *manufacturing* — Two laser passes interfere through the shared heat-affected zone, and the interference sets the residual stress. *Mech:* the second pass tempers the first. *Kill:* stress additive across passes.

B389 · *acoustics-vibration* — Two sources interfere through the shared room mode, and the interference sets the measured power. *Mech:* the modal coupling is not additive. *Kill:* power additive across sources.

B390 · *signal-information* — Two channels interfere through the shared clock, and the interference sets the crosstalk. *Mech:* the clock's jitter is correlated. *Kill:* crosstalk independent of clock sharing.

Operator 14 — Selection inversion

The sample selected itself in a way that guarantees the result. The bias has a shape, and the shape is measurable.

B391 · *condensed-matter* — Reported superconductors are selected for being easy to make, and the selection biases the apparent Tc–structure relation. *Mech:* the materials that form at ambient pressure are a non-random subset. *Kill:* the relation unchanged in a pressure-synthesised sample.

B392 · *soft-matter* — Reported gel moduli are selected for being measurable, and the selection truncates the modulus distribution. *Mech:* stiff gels are measured by rheology, soft ones by microrheology, and the two are not comparable. *Kill:* distributions matching across methods.

B393 · *electrochemistry* — Reported catalyst stability is selected for surviving the first hour, and the selection hides the fast-failing majority. *Mech:* the survival criterion is a filter on the decay's initial rate. *Kill:* stability distribution including failures matching the reported one.

B394 · *catalysis* — Reported turnover frequencies are selected for catalysts that were characterised successfully, and the selection biases toward high surface area. *Mech:* the characterisation's success depends on the material's morphology. *Kill:* TOF distribution including uncharacterised samples.

B395 · *photochemistry* — Reported quantum yields are selected for emitters bright enough to measure, and the selection truncates the low-yield tail. *Mech:* the detection limit sets the truncation. *Kill:* yield distribution measured with a brighter detection scheme.

B396 · *ultrafast* — Reported relaxation times are selected for samples that survived the laser, and the selection biases toward robust materials. *Mech:* the damage threshold correlates with the lattice strength, which correlates with the relaxation. *Kill:* relaxation distribution including damaged samples.

B397 · *quantum-devices* — Reported coherence times are selected for qubits that were measurable, and the selection biases toward the sweet spot. *Mech:* the measurement requires the qubit to be tunable to a working point. *Kill:* coherence distribution including untunable devices.

B398 · *precision-metrology* — Reported clock comparisons are selected for agreement, and the selection hides the discrepant runs. *Mech:* the analysis pipeline's rejection criteria are correlated with the systematic. *Kill:* distribution including rejected runs matching the accepted one.

B399 · *nuclear-particle* — Reported cross sections are selected for detectable final states, and the selection biases the branching ratios. *Mech:* the detection efficiency correlates with the decay mode. *Kill:* branching ratios including undetected modes.

B400 · *astrophysics* — Reported exoplanet radii are selected for transiting geometry, and the selection biases the radius distribution at small sizes. *Mech:* the transit probability scales inversely with the orbital radius. *Kill:* radius distribution corrected for geometry matching the reported one.

B401 · *planetary* — Reported crater ages are selected for well-preserved surfaces, and the selection biases the age distribution young. *Mech:* the preservation correlates with the age. *Kill:* age distribution including degraded surfaces.

B402 · *geophysics* — Reported slow slip events are selected for instrumented faults, and the selection biases the moment release. *Mech:* the instrumentation correlates with the fault's accessibility. *Kill:* moment distribution including uninstrumented faults.

B403 · *atmosphere* — Reported extreme rainfall is selected for gauge density, and the selection biases the trend. *Mech:* the gauge density changed with the observing system. *Kill:* trend corrected for density matching the reported one.

B404 · *ocean-ice* — Reported ice thickness is selected for cloud-free scenes, and the selection biases the distribution thin. *Mech:* the cloud cover correlates with the weather, which correlates with the thickness. *Kill:* distribution including cloudy scenes.

B405 · *hydrology-soil* — Reported catchment yields are selected for gauged catchments, and the selection biases the water balance. *Mech:* the gauging correlates with the catchment's size and land use. *Kill:* balance including ungauged catchments.

B406 · *microbiology* — Reported mutation rates are selected for strains that grow, and the selection biases the rate low. *Mech:* the mutator strains are less viable. *Kill:* rate including non-growing strains.

B407 · *plant-agriculture* — Reported drought tolerance is selected for varieties that survived the trial, and the selection biases the tolerance high. *Mech:* the survival correlates with the tolerance. *Kill:* tolerance including failed varieties.

B408 · *neuroscience* — Reported neural recordings are selected for cells with stable isolation, and the selection biases the firing rate. *Mech:* the isolation correlates with the cell's size and firing. *Kill:* rate distribution including unstable recordings.

B409 · *immunology* — Reported antibody affinities are selected for clones that survived sorting, and the selection biases the affinity high. *Mech:* the sorting gate correlates with the affinity. *Kill:* affinity distribution including unsorted clones.

B410 · *developmental-biology* — Reported phenotypes are selected for embryos that developed normally, and the selection biases the phenotype's penetrance. *Mech:* the abnormality correlates with the genotype. *Kill:* penetrance including abnormal embryos.

B411 · *ecology-evolution* — Reported extinction rates are selected for well-fossilised taxa, and the selection biases the rate. *Mech:* the fossilisation correlates with the shell chemistry. *Kill:* rate including poorly fossilised taxa.

B412 · *medicine-diagnostics* — Reported test performance is selected for patients who completed the reference standard, and the selection biases the sensitivity. *Mech:* the completion correlates with the disease severity. *Kill:* performance including non-completers.

B413 · *pharmacology* — Reported bioavailability is selected for formulations that dissolved, and the selection biases the estimate high. *Mech:* the dissolution correlates with the absorption. *Kill:* bioavailability including poor dissolvers.

B414 · *food-science* — Reported shelf life is selected for batches that passed, and the selection biases the estimate long. *Mech:* the failure correlates with the batch's microbial load. *Kill:* shelf life including failed batches.

B415 · *materials-failure* — Reported fatigue lives are selected for specimens that failed in the gauge, and the selection biases the life short. *Mech:* the failure location correlates with the life. *Kill:* life distribution including out-of-gauge failures.

B416 · *structural-civil* — Reported seismic performance is selected for buildings that were inspected, and the selection biases the damage high. *Mech:* the inspection correlates with the visible damage. *Kill:* damage distribution including uninspected buildings.

B417 · *energy-systems* — Reported cycle lives are selected for cells that completed the test, and the selection biases the life long. *Mech:* the completion correlates with the life. *Kill:* life distribution including incomplete tests.

B418 · *manufacturing* — Reported yields are selected for lines that were audited, and the selection biases the yield high. *Mech:* the audit correlates with the line's maturity. *Kill:* yield including unaudited lines.

B419 · *acoustics-vibration* — Reported absorption coefficients are selected for samples that fit the tube, and the selection biases the coefficient. *Mech:* the fit correlates with the sample's stiffness. *Kill:* coefficient including ill-fitting samples.

B420 · *signal-information* — Reported channel capacities are selected for favourable channel realisations, and the selection biases the capacity high. *Mech:* the realisations correlate with the measurement's duration. *Kill:* capacity including unfavourable realisations.

Operator 15 — Units and definition traps

A unit convention, a reference state, or a definition carries a hidden degree of freedom that moves the number.

B421 · *condensed-matter* — The reported carrier mobility depends on whether the sheet density is quoted per square or per unit volume, and the conversion hides a factor of the film's thickness. *Mech:* the thickness is often assumed rather than measured. *Kill:* mobility independent of the measured thickness across a thickness series.

B422 · *soft-matter* — The reported particle size depends on whether the distribution is weighted by number, volume, or intensity. *Mech:* the weighting is a definition, and the three differ by more than the polydispersity. *Kill:* the three

weightings agreeing within the polydispersity.

B423 · *electrochemistry* — The reported capacitance depends on whether it is quoted per geometric area or per ECSA, and the ratio varies by 100×. *Mech:* the roughness factor is assumed, not measured. *Kill:* the ratio agreeing across materials with measured roughness.

B424 · *catalysis* — The reported rate depends on whether it is normalised by mass or by surface area, and the choice changes the ranking. *Mech:* the two normalisations weight the particle size differently. *Kill:* the ranking identical under both normalisations.

B425 · *photochemistry* — The reported quantum yield depends on whether it is defined per absorbed or per incident photon. *Mech:* the distinction matters at high absorbance. *Kill:* the two definitions agreeing at high absorbance.

B426 · *ultrafast* — The reported pulse energy depends on whether it is quoted before or after the compressor's loss. *Mech:* the loss is often unmeasured. *Kill:* energy independent of the measurement point.

B427 · *quantum-devices* — The reported gate fidelity depends on whether it is quoted with or without SPAM correction. *Mech:* the correction removes a large, state-dependent error. *Kill:* corrected and uncorrected fidelities agreeing.

B428 · *precision-metrology* — The reported stability depends on whether the fractional or absolute frequency is used in the Allan variance. *Mech:* the normalisation by the carrier. *Kill:* stability independent of the normalisation.

B429 · *nuclear-particle* — The reported cross section depends on whether it is quoted in the lab or centre-of-mass frame. *Mech:* the transformation's Jacobian. *Kill:* cross sections agreeing in both frames.

B430 · *astrophysics* — The reported luminosity depends on the assumed cosmology. *Mech:* the distance modulus's cosmology dependence. *Kill:* luminosity independent of the assumed cosmology at low redshift.

B431 · *planetary* — The reported crater age depends on the assumed production function. *Mech:* the function's slope sets the age. *Kill:* age independent of the production function's choice.

B432 · *geophysics* — The reported magnitude depends on whether the local or moment magnitude is used. *Mech:* the saturation at large events. *Kill:* the two agreeing at large magnitude.

B433 · *atmosphere* — The reported aerosol optical depth depends on the assumed angstrom exponent. *Mech:* the retrieval's two-wavelength closure. *Kill:* the depth independent of the assumed exponent.

B434 · *ocean-ice* — The reported ice concentration depends on the tie point's assumed emissivity. *Mech:* the emissivity's variability. *Kill:* concentration independent of the tie point.

B435 · *hydrology-soil* — The reported discharge depends on the rating curve's extrapolation. *Mech:* the curve's exponent. *Kill:* discharge measured directly at high flow.

B436 · *microbiology* — The reported CFU depends on the plating medium's recovery efficiency. *Mech:* the recovery is strain-dependent. *Kill:* CFU independent of the medium.

B437 · *plant-agriculture* — The reported yield depends on the moisture content's reference. *Mech:* the standard reference is a convention. *Kill:* yield independent of the reference at fixed moisture.

B438 · *neuroscience* — The reported spike rate depends on whether multi-unit activity is included. *Mech:* the sorting's threshold. *Kill:* rate independent of the threshold.

B439 · *immunology* — The reported titre depends on the endpoint's definition. *Mech:* the interpolation versus the threshold. *Kill:* titre independent of the definition.

B440 · *developmental-biology* — The reported stage depends on the reference's temperature. *Mech:* the staging series is temperature-normalised. *Kill:* stage independent of the rearing temperature.

B441 · *ecology-evolution* — The reported diversity depends on the taxonomic resolution. *Mech:* the lumping versus splitting. *Kill:* diversity ranking independent of the resolution.

B442 · *medicine-diagnostics* — The reported prevalence depends on the denominator's definition. *Mech:* the tested versus the eligible population. *Kill:* prevalence independent of the denominator.

B443 · *pharmacology* — The reported dose depends on whether it is the salt or the base. *Mech:* the counterion's mass. *Kill:* dose equivalence stated consistently across the literature.

B444 · *food-science* — The reported calorie content depends on the Atwater factor's assignment. *Mech:* the fibre's assignment. *Kill:* content independent of the assignment.

B445 · *materials-failure* — The reported hardness depends on the indenter's geometry and the load. *Mech:* the size effect. *Kill:* hardness independent of load above the size-effect regime.

B446 · *structural-civil* — The reported strength depends on the specimen's shape factor. *Mech:* the shape factor is a convention. *Kill:* strength independent of the shape factor after conversion.

B447 · *energy-systems* — The reported capacity depends on whether it is quoted at C/20 or 1C. *Mech:* the rate dependence. *Kill:* capacity independent of rate.

B448 · *manufacturing* — The reported tolerance depends on the datum's choice. *Mech:* the datum chain accumulates. *Kill:* tolerance independent of the datum.

B449 · *acoustics-vibration* — The reported level depends on whether it is A-weighted or flat. *Mech:* the weighting's frequency dependence. *Kill:* level independent of the weighting.

B450 · *signal-information* — The reported SNR depends on whether it is quoted in the noise or the signal bandwidth. *Mech:* the bandwidth's definition. *Kill:* SNR independent of the bandwidth convention.

Discovery07 — The Black Swan Grid, operators 16–20

Operator 16 — Coincidence of time constants

Two unrelated processes relax on the same timescale. The experiment attributes both to one, and the separation is possible only by varying a third parameter.

B451 · *condensed-matter* — The electron–phonon relaxation time and the thermal diffusion time across a film coincide at a specific thickness, and every measurement in that window misattributes one to the other. *Mech:* both scale with thickness but with different powers, so they cross. *Kill:* relaxation time independent of thickness at the crossing.

B452 · *soft-matter* — The polymer's reptation time and the particle's Brownian time coincide at a specific radius, and the composite's rheology is misread as a glass transition. *Mech:* the two mechanisms produce the same frequency dependence at the crossing. *Kill:* the crossing absent when the polymer length is changed.

B453 · *electrochemistry* — The double-layer charging time and the faradaic time constant coincide at a specific electrode size, and impedance misassigns the arc. *Mech:* both scale with area but differently. *Kill:* arc assignment independent of electrode size.

B454 · *catalysis* — The surface reaction's turnover time and the pore diffusion time coincide at a specific pellet size, and the apparent kinetics are neither. *Mech:* the Thiele modulus equals one there. *Kill:* kinetics independent of pellet size at the crossing.

B455 · *photochemistry* — The radiative lifetime and the diffusion-limited quenching time coincide at a specific quencher concentration, and the Stern–Volmer plot bends. *Mech:* the two rates are equal there. *Kill:* linear Stern–Volmer through the predicted concentration.

B456 · *ultrafast* — The carrier–carrier scattering time and the probe's temporal resolution coincide at a specific fluence, and the measured rise is the instrument. *Mech:* the scattering accelerates with density. *Kill:* rise time independent of fluence at the crossing.

B457 · *quantum-devices* — The qubit's relaxation time and the readout's integration time coincide at a specific setting, and the extracted T_1 is the readout's. *Mech:* the readout's bandwidth sets the measured decay. *Kill:* T_1 independent of the integration time.

B458 · *precision-metrology* — The servo's time constant and the clock's intermodulation time coincide, and the stability floor is the loop's. *Mech:* the loop's transfer function shapes the noise. *Kill:* floor independent of the loop's bandwidth.

B459 · *nuclear-particle* — The scintillator's decay time and the photodetector's transit-time spread coincide, and the pulse-shape discrimination fails. *Mech:* both contribute equally to the rise. *Kill:* discrimination restored with a faster detector.

B460 · *astrophysics* — The accretion disc's thermal time and the viscous time coincide at a specific radius, and the variability is misattributed. *Mech:* the two cross at a computable radius. *Kill:* variability timescale independent of the radius.

B461 · *planetary* — The surface's thermal inertia time and the diurnal period coincide at a specific latitude, and the retrieved property is degenerate. *Mech:* the thermal skin depth equals the diurnal depth. *Kill:* retrieval independent of latitude

at the crossing.

B462 · *geophysics* — The earthquake's rupture duration and the station's site response time coincide for small events, and the magnitude is overestimated. *Mech:* the site's reverberation adds to the source duration. *Kill:* magnitude independent of the site's response.

B463 · *atmosphere* — The boundary layer's turnover time and the surface flux's response time coincide at a specific stability, and the flux measurement is biased. *Mech:* the eddy covariance's averaging window matches the turnover. *Kill:* flux independent of the averaging window.

B464 · *ocean-ice* — The ice's conductive time and the snow's insulating time coincide at a specific snow depth, and the thickness retrieval is degenerate. *Mech:* both set the surface temperature equally. *Kill:* retrieval independent of the snow depth.

B465 · *hydrology-soil* — The infiltration time and the evaporation time coincide at a specific soil texture, and the water balance is misattributed. *Mech:* both remove water at the same rate. *Kill:* balance independent of the texture at the crossing.

B466 · *microbiology* — The doubling time and the dilution time in a chemostat coincide at a specific rate, and the steady state is misidentified. *Mech:* the washout and growth balance at that rate. *Kill:* steady state independent of the dilution rate.

B467 · *plant-agriculture* — The stomatal opening time and the humidity's response time coincide, and the conductance measurement is the sensor's. *Mech:* both have the same time constant. *Kill:* conductance independent of the sensor's response time.

B468 · *neuroscience* — The synaptic decay time and the membrane's time constant coincide at a specific input resistance, and the synaptic conductance is misestimated. *Mech:* the two are indistinguishable in voltage clamp. *Kill:* conductance independent of the input resistance.

B469 · *immunology* — The receptor's internalisation time and the ligand's dissociation time coincide, and the affinity is underestimated. *Mech:* the two processes remove the complex at the same rate. *Kill:* affinity independent of the internalisation rate.

B470 · *developmental-biology* — The cell cycle's period and the morphogen's decay time coincide, and the patterning is misattributed to a gradient. *Mech:* the two timescales are equal, so the pattern is dynamic. *Kill:* pattern independent of the cycle's period.

B471 · *ecology-evolution* — The generation time and the environmental fluctuation time coincide, and adaptation is misattributed to selection. *Mech:* the fluctuation's period matches the generation. *Kill:* adaptation independent of the fluctuation's period.

B472 · *medicine-diagnostics* — The biomarker's half-life and the sampling interval coincide, and the peak is missed. *Mech:* the sampling aliases the decay. *Kill:* peak recovered with a shorter interval.

B473 · *pharmacology* — The absorption time and the elimination time coincide for a specific drug, and the half-life is misestimated. *Mech:* the flip-flop kinetics. *Kill:* half-life independent of the dosing route.

B474 · *food-science* — The crystallisation time and the cooling time coincide at a specific rate, and the crystal size is set by the process rather than the formulation. *Mech:* the nucleation and growth compete. *Kill:* size independent of the cooling rate.

B475 · *materials-failure* — The crack's incubation time and the test's ramp time coincide, and the toughness is overestimated. *Mech:* the crack grows during the ramp. *Kill:* toughness independent of the ramp rate.

B476 · *structural-civil* — The structure's period and the ground motion's period coincide, and the response is resonant rather than representative. *Mech:* the spectral acceleration peaks at the structure's period. *Kill:* response independent of the structure's period.

B477 · *energy-systems* — The cell's thermal time constant and the charge's duration coincide at a specific rate, and the temperature rise is underestimated. *Mech:* the heat accumulates faster than it dissipates. *Kill:* rise independent of the charge rate.

B478 · *manufacturing* — The melt's solidification time and the scan's inter-pass time coincide, and the microstructure is set by the scan strategy. *Mech:* the two compete. *Kill:* microstructure independent of the scan strategy.

B479 · *acoustics-vibration* — The room's modal decay time and the source's duration coincide, and the measured absorption is the source's. *Mech:* the decay is truncated by the source. *Kill:* absorption independent of the source's duration.

B480 · *signal-information* — The channel's coherence time and the symbol period coincide, and the capacity estimate is biased. *Mech:* the pilot overhead changes at the crossing. *Kill:* capacity independent of the symbol period.

Operator 17 — Geometric frustration

The system cannot satisfy all its constraints at once. The compromise it adopts is mistaken for a different phenomenon.

B481 · *condensed-matter* — A thin film on a rigid substrate cannot relax its thermal expansion, so its measured transition temperature is a frustration temperature rather than a bulk one. *Mech:* the biaxial strain shifts the transition by the Ehrenfest relation. *Kill:* transition temperature matching bulk on a compliant substrate.

B482 · *soft-matter* — A confined colloidal crystal cannot close its lattice, so its melting temperature is depressed in a way set by the pore's commensurability. *Mech:* the strain energy from the mismatch. *Kill:* melting point independent of pore diameter.

B483 · *electrochemistry* — An intercalation electrode cannot satisfy both charge neutrality and lattice matching, so its voltage plateau is a frustration plateau. *Mech:* the coherency strain shifts the plateau's potential. *Kill:* plateau potential independent of the particle size.

B484 · *catalysis* — A bimetallic surface cannot match both reactants' preferred sites, so its activity peak is at a composition set by the mismatch. *Mech:* the two adsorbates' optimal lattice constants differ. *Kill:* peak at the same composition for both reactants.

B485 · *photochemistry* — A chromophore in a rigid matrix cannot relax its excited state, so its emission is a frustration spectrum with a characteristic shape. *Mech:* the matrix's stiffness sets the reorganization energy. *Kill:* spectrum independent of the matrix's stiffness.

B486 · *ultrafast* — A photoexcited lattice cannot expand on the electronic timescale, so the transient is a frustrated expansion with a measurable acoustic signature. *Mech:* the stress builds until the acoustic wave launches. *Kill:* no acoustic signature at the electronic timescale.

B487 · *quantum-devices* — A qubit coupled to two resonators cannot satisfy both matching conditions, so its Purcell protection is compromised at a computable detuning. *Mech:* the two couplings interfere. *Kill:* protection independent of the second resonator's detuning.

B488 · *precision-metrology* — A clock's interrogation cannot satisfy both the Ramsey and the Rabi conditions, so its lineshape is a frustration shape with a shifted centre. *Mech:* the two pulse areas compete. *Kill:* centre independent of the pulse area.

B489 · *nuclear-particle* — A detector cannot satisfy both energy and timing resolution, and the compromise point is a computable operating condition. *Mech:* the shaping time trades the two. *Kill:* both improved simultaneously at the same shaping.

B490 · *astrophysics* — A disc cannot satisfy both thermal and viscous equilibrium, and the mismatch drives the variability. *Mech:* the two timescales differ, producing limit cycles. *Kill:* steady emission at the predicted mismatch.

B491 · *planetary* — A planet's crust cannot satisfy both isostasy and elastic support, and the resulting gravity anomaly is a frustration pattern. *Mech:* the elastic thickness sets the compromise. *Kill:* anomaly consistent with pure isostasy.

B492 · *geophysics* — A fault cannot satisfy both the loading rate and the healing rate, and the resulting recurrence is a frustration period. *Mech:* the two rates compete. *Kill:* recurrence independent of the healing rate.

B493 · *atmosphere* — A cloud cannot satisfy both the updraft's supply and the entrainment's dilution, and its droplet spectrum is a frustration spectrum. *Mech:* the two compete at the cloud's edge. *Kill:* spectrum independent of the entrainment rate.

B494 · *ocean-ice* — Sea ice cannot satisfy both the salinity and the volume constraints, and the resulting brine network is a frustration pattern. *Mech:* the salt's exclusion competes with the ice's expansion. *Kill:* network independent of the growth rate.

B495 · *hydrology-soil* — A soil cannot satisfy both the infiltration and the drainage constraints, and the resulting moisture profile is a frustration profile. *Mech:* the capillary and gravity forces compete. *Kill:* profile independent of the layer's thickness.

B496 · *microbiology* — A cell cannot satisfy both the growth and the division constraints, and the resulting size is a frustration size. *Mech:* the two sizers compete. *Kill:* size independent of the growth rate.

B497 · *plant-agriculture* — A leaf cannot satisfy both the carbon gain and the water loss, and its stomatal conductance is a frustration optimum. *Mech:* the marginal water cost sets the compromise. *Kill:* conductance independent of the humidity.

B498 · *neuroscience* — A neuron cannot satisfy both the firing rate and the energy budget, and its rate is a frustration rate. *Mech:* the two constraints intersect. *Kill:* rate independent of the energy supply.

B499 · *immunology* — A B cell cannot satisfy both the affinity and the self-tolerance constraints, and its selection is a frustration selection. *Mech:* the two thresholds compete. *Kill:* selection independent of the self-antigen's avidity.

B500 · *developmental-biology* — A tissue cannot satisfy both the growth and the patterning constraints, and its size is a frustration size. *Mech:* the two scales compete. *Kill:* size independent of the patterning's wavelength.

B501 · *ecology-evolution* — A population cannot satisfy both the growth and the predation constraints, and its abundance is a frustration abundance. *Mech:* the two rates balance at a fixed point. *Kill:* abundance independent of the predation

rate.

B502 · *medicine-diagnostics* — A diagnostic cannot satisfy both the sensitivity and the specificity constraints, and its operating point is a frustration point. *Mech:* the threshold trades the two. *Kill:* both improved at the same threshold.

B503 · *pharmacology* — A drug cannot satisfy both the potency and the selectivity constraints, and its profile is a frustration profile. *Mech:* the two binding pockets overlap. *Kill:* potency and selectivity independent at fixed scaffold.

B504 · *food-science* — A formulation cannot satisfy both the texture and the stability constraints, and its structure is a frustration structure. *Mech:* the two phase behaviours compete. *Kill:* texture independent of the stability.

B505 · *materials-failure* — A coating cannot satisfy both the hardness and the toughness constraints, and its performance is a frustration optimum. *Mech:* the two properties trade through the grain size. *Kill:* both improved at the same grain size.

B506 · *structural-civil* — A frame cannot satisfy both the stiffness and the ductility constraints, and its design is a frustration design. *Mech:* the two trade through the reinforcement ratio. *Kill:* both improved at the same ratio.

B507 · *energy-systems* — A cell cannot satisfy both the energy and the power constraints, and its electrode is a frustration electrode. *Mech:* the thickness trades the two. *Kill:* both improved at the same thickness.

B508 · *manufacturing* — A process cannot satisfy both the speed and the tolerance constraints, and its operating point is a frustration point. *Mech:* the thermal error grows with speed. *Kill:* tolerance independent of speed.

B509 · *acoustics-vibration* — A panel cannot satisfy both the transmission loss and the weight constraints, and its design is a frustration design. *Mech:* the mass law trades the two. *Kill:* loss improved at fixed mass.

B510 · *signal-information* — A code cannot satisfy both the rate and the distance constraints, and its performance is a frustration performance. *Mech:* the Singleton bound. *Kill:* a code exceeding the bound.

Operator 18 — Noise as resource

The fluctuation that is averaged away contains a quantity the mean cannot express.

B511 · *condensed-matter* — The current noise of a disordered conductor measures its mesoscopic geometry, not just its resistance. *Mech:* the noise's Fano factor depends on the number of open channels. *Kill:* Fano factor independent of the measured channel count.

B512 · *soft-matter* — The Brownian fluctuation of a trapped particle measures the medium's viscoelasticity at frequencies no rheometer reaches. *Mech:* the fluctuation's spectrum is the medium's response by the fluctuation–dissipation theorem. *Kill:* spectrum inconsistent with the rheometer at overlapping frequencies.

B513 · *electrochemistry* — The electrochemical noise measures the corrosion's localisation, not just its rate. *Mech:* the noise's power scales with the pitting's stochasticity. *Kill:* noise power independent of the measured pit density.

B514 · *catalysis* — The rate fluctuation measures the number of active sites, not just the turnover. *Mech:* the fluctuation's variance is inversely proportional to the site count. *Kill:* variance independent of the measured site count.

B515 · *photochemistry* — The photon-counting noise measures the emitter's quantum yield without a reference. *Mech:* the Mandel parameter is set by the yield. *Kill:* Mandel parameter independent of the yield.

B516 · *ultrafast* — The shot-to-shot fluctuation measures the pulse's coherence, not its energy stability. *Mech:* the fluctuation's spectrum carries the carrier-envelope phase noise. *Kill:* spectrum independent of the phase noise.

B517 · *quantum-devices* — The qubit's dephasing noise measures the bath's temperature without a thermometer. *Mech:* the noise's asymmetry in frequency is set by the bath's occupation. *Kill:* asymmetry independent of the cryostat's temperature.

B518 · *precision-metrology* — The clock's Dick effect measures the local oscillator's noise at the interrogation frequency. *Mech:* the aliasing of the oscillator's noise. *Kill:* effect independent of the oscillator's measured noise.

B519 · *nuclear-particle* — The detector's baseline fluctuation measures its temperature, not its gain. *Mech:* the leakage current's shot noise scales with temperature. *Kill:* fluctuation independent of the measured temperature.

B520 · *astrophysics* — The light curve's flickering measures the accretion disc's viscosity. *Mech:* the flickering's power spectrum is set by the viscous timescale. *Kill:* spectrum independent of the measured viscosity.

B521 · *planetary* — The thermal infrared's fluctuation measures the regolith's grain size. *Mech:* the fluctuation's spectrum is set by the grain-scale heat capacity. *Kill:* spectrum independent of the measured grain size.

B522 · *geophysics* — The ambient seismic noise measures the subsurface's attenuation. *Mech:* the noise's decay with distance is set by the attenuation. *Kill:* attenuation independent of the noise's decay.

B523 · *atmosphere* — The turbulence's fluctuation measures the surface's roughness. *Mech:* the spectrum's inertial range is set by the roughness length. *Kill:* spectrum independent of the measured roughness.

B524 · *ocean-ice* — The ice's acoustic emission measures its deformation rate. *Mech:* the emission's rate scales with the strain rate. *Kill:* emission rate independent of the measured strain.

B525 · *hydrology-soil* — The soil's moisture fluctuation measures its hydraulic conductivity. *Mech:* the fluctuation's spectrum is set by the drainage time. *Kill:* spectrum independent of the measured conductivity.

B526 · *microbiology* — The gene expression's noise measures the promoter's state, not its mean. *Mech:* the noise's Fano factor distinguishes bursting from Poisson. *Kill:* Fano factor independent of the measured promoter state.

B527 · *plant-agriculture* — The stomatal conductance's fluctuation measures the plant's hydraulic capacitance. *Mech:* the fluctuation's spectrum is set by the capacitance. *Kill:* spectrum independent of the measured capacitance.

B528 · *neuroscience* — The membrane potential's noise measures the synapse count. *Mech:* the noise's variance scales with the number of independent inputs. *Kill:* variance independent of the measured synapse count.

B529 · *immunology* — The cytokine's fluctuation measures the cell's activation state. *Mech:* the burst size and frequency distinguish the state. *Kill:* fluctuation independent of the measured state.

B530 · *developmental-biology* — The morphogen's fluctuation measures the tissue's position accuracy. *Mech:* the positional error scales with the fluctuation divided by the gradient. *Kill:* error independent of the measured fluctuation.

B531 · *ecology-evolution* — The population's fluctuation measures its resilience. *Mech:* the return time to equilibrium is set by the dominant eigenvalue. *Kill:* return time independent of the measured fluctuation.

B532 · *medicine-diagnostics* — The biomarker's fluctuation measures the homeostatic setpoint's strength. *Mech:* the fluctuation's variance is set by the feedback gain. *Kill:* variance independent of the measured gain.

B533 · *pharmacology* — The plasma concentration's fluctuation measures the absorption's stochasticity. *Mech:* the fluctuation's spectrum is set by the dissolution's randomness. *Kill:* spectrum independent of the measured dissolution.

B534 · *food-science* — The texture's fluctuation measures the bubble size distribution. *Mech:* the acoustic emission's spectrum is set by the bubble size. *Kill:* spectrum independent of the measured size.

B535 · *materials-failure* — The acoustic emission's fluctuation measures the crack's growth rate. *Mech:* the emission's rate scales with the growth rate. *Kill:* emission rate independent of the measured growth rate.

B536 · *structural-civil* — The ambient vibration's fluctuation measures the structure's damage. *Mech:* the modal bandwidth widens with damage. *Kill:* bandwidth independent of the measured damage.

B537 · *energy-systems* — The cell's voltage fluctuation measures its internal resistance. *Mech:* the fluctuation's spectrum is set by the RC time constant. *Kill:* spectrum independent of the measured resistance.

B538 · *manufacturing* — The process's dimension fluctuation measures the tool's wear. *Mech:* the variance grows with the wear's progression. *Kill:* variance independent of the measured wear.

B539 · *acoustics-vibration* — The room's noise floor measures its absorption at low frequency. *Mech:* the modal density sets the floor's spectrum. *Kill:* floor independent of the measured absorption.

B540 · *signal-information* — The quantiser's noise measures its effective number of bits. *Mech:* the noise's variance is set by the step size. *Kill:* variance independent of the measured step size.

Operator 19 — The dead channel

An instrument channel that is unused, disabled, or discarded holds the measurement nobody thought to make.

B541 · *condensed-matter* — The cryostat's unused thermometry channel measures the sample's thermal conductance. *Mech:* the channel's reading is the sample's temperature, not the bath's. *Kill:* channel reading identical to the bath across a conductance series.

B542 · *soft-matter* — The rheometer's normal-force channel measures the sample's compressibility. *Mech:* the force is set by the sample's bulk modulus at fixed gap. *Kill:* force independent of the measured modulus.

B543 · *electrochemistry* — The potentiostat's unused auxiliary channel measures the electrolyte's resistance. *Mech:* the channel's voltage is the IR drop. *Kill:* channel voltage independent of the measured resistance.

B544 · *catalysis* — The reactor's unused pressure-drop channel measures the bed's compaction. *Mech:* the drop is set by the bed's void fraction. *Kill:* drop independent of the measured compaction.

B545 · *photochemistry* — The spectrophotometer's reference channel measures the lamp's aging. *Mech:* the reference's drift is the lamp's output decay. *Kill:* reference drift independent of the measured lamp output.

B546 · *ultrafast* — The oscillator's unused error channel measures the laser's timing jitter. *Mech:* the error signal is the phase difference. *Kill:* error signal independent of the measured jitter.

B547 · *quantum-devices* — The cryostat's unused flux-line channel measures the magnetic field's noise. *Mech:* the line's induced current is the field's derivative. *Kill:* current independent of the measured field noise.

B548 · *precision-metrology* — The clock's unused correction channel measures the laboratory's pressure. *Mech:* the collisional shift is proportional to pressure. *Kill:* correction independent of the measured pressure.

B549 · *nuclear-particle* — The detector's unused timing channel measures the interaction depth. *Mech:* the drift time is set by the depth. *Kill:* timing independent of the measured depth.

B550 · *astrophysics* — The telescope's unused guider channel measures the atmospheric seeing. *Mech:* the guider's image motion is the seeing. *Kill:* motion independent of the measured seeing.

B551 · *planetary* — The spacecraft's unused star-tracker channel measures the solar radiation pressure. *Mech:* the tracker's bias is set by the pressure's torque. *Kill:* bias independent of the measured pressure.

B552 · *geophysics* — The seismometer's unused mass-position channel measures the instrument's tilt. *Mech:* the position offset is the tilt. *Kill:* offset independent of the measured tilt.

B553 · *atmosphere* — The sonde's unused GPS altitude channel measures the balloon's ascent rate. *Mech:* the altitude's derivative is the rate. *Kill:* rate independent of the measured ascent.

B554 · *ocean-ice* — The buoy's unused conductivity channel measures the ice's growth rate. *Mech:* the near-surface salinity tracks the growth. *Kill:* conductivity independent of the measured growth.

B555 · *hydrology-soil* — The logger's unused battery-voltage channel measures the soil's temperature. *Mech:* the battery's voltage has a temperature coefficient. *Kill:* voltage independent of the measured temperature.

B556 · *microbiology* — The plate reader's unused fluorescence channel measures the medium's pH. *Mech:* the medium's autofluorescence is pH-dependent. *Kill:* autofluorescence independent of the measured pH.

B557 · *plant-agriculture* — The chamber's unused CO_2 channel measures the soil's respiration. *Mech:* the chamber's CO_2 rise in the dark is the respiration. *Kill:* rise independent of the measured respiration.

B558 · *neuroscience* — The amplifier's unused reference channel measures the animal's movement. *Mech:* the movement artifact appears on the reference. *Kill:* artifact independent of the measured movement.

B559 · *immunology* — The plate's unused blank well measures the assay's drift. *Mech:* the blank's signal is the reagent's degradation. *Kill:* blank independent of the measured drift.

B560 · *developmental-biology* — The microscope's unused transmitted-light channel measures the embryo's opacity. *Mech:* the opacity tracks the developmental stage. *Kill:* opacity independent of the measured stage.

B561 · *ecology-evolution* — The acoustic recorder's unused ultrasonic channel measures the insect community. *Mech:* the ultrasound is the insect chorus. *Kill:* ultrasonic power independent of the measured insect abundance.

B562 · *medicine-diagnostics* — The ECG's unused lead measures the patient's hydration. *Mech:* the lead's amplitude tracks the thoracic impedance. *Kill:* amplitude independent of the measured hydration.

B563 · *pharmacology* — The infusion pump's unused pressure channel measures the vein's compliance. *Mech:* the pressure rise is set by the compliance. *Kill:* rise independent of the measured compliance.

B564 · *food-science* — The oven's unused humidity channel measures the product's moisture loss. *Mech:* the humidity rise is the loss. *Kill:* rise independent of the measured loss.

B565 · *materials-failure* — The test machine's unused crosshead channel measures the specimen's compliance. *Mech:* the crosshead's motion includes the load train's deflection. *Kill:* compliance independent of the measured deflection.

B566 · *structural-civil* — The monitoring system's unused temperature channel measures the structure's solar exposure. *Mech:* the temperature rise is the absorbed flux. *Kill:* rise independent of the measured flux.

B567 · *energy-systems* — The charger's unused coulomb-counting channel measures the cell's self-discharge. *Mech:* the count's drift is the self-discharge. *Kill:* drift independent of the measured self-discharge.

B568 · *manufacturing* — The machine's unused spindle-load channel measures the tool's sharpness. *Mech:* the load rises with the wear. *Kill:* load independent of the measured wear.

B569 · *acoustics-vibration* — The loudspeaker's unused impedance channel measures the room's loading. *Mech:* the cone's impedance is set by the room's pressure. *Kill:* impedance independent of the measured room.

B570 · *signal-information* — The receiver's unused RSSI channel measures the channel's multipath. *Mech:* the signal's fluctuation is the fading. *Kill:* fluctuation independent of the measured multipath.

Operator 20 — Archive resurrection

An old dataset or instrument was retired before the question it can answer was asked.

B571 · *condensed-matter* — 1970s resistivity data on annealed metals contains the vacancy formation energy, recoverable because the annealing schedules were recorded. *Mech:* the resistivity's recovery stages map to the defect's migration energy. *Kill:* recovery stages not reproducible from the recorded schedules.

B572 · *soft-matter* — Archived rheology on industrial polymers answers the tube-model question because their molecular weights were measured by an obsolete method that was more accurate. *Mech:* the old method's calibration is recoverable from the archive's standards. *Kill:* the old and new molecular weights disagreeing systematically.

B573 · *electrochemistry* — Retired battery cycling data contains the SEI's growth law, recoverable from the capacity-fade curvature. *Mech:* the fade's square-root component is the SEI. *Kill:* fade curvature inconsistent with any SEI growth law.

B574 · *catalysis* — Old pilot-plant data contains the catalyst's deactivation order, recoverable because the feed composition was logged. *Mech:* the deactivation's order in poison is in the decay's shape. *Kill:* decay shape independent of the logged poison.

B575 · *photochemistry* — Archived quantum-yield data contains the solvent's polarity scale, recoverable because the solvents were catalogued. *Mech:* the yield's dependence on the solvent's dielectric constant. *Kill:* no correlation recoverable from the catalogue.

B576 · *ultrafast* — Retired streak-camera data contains the pulse's third-order correlation, recoverable because the sweep was linear. *Mech:* the trace's asymmetry is the third-order moment. *Kill:* asymmetry inconsistent with any linear sweep.

B577 · *quantum-devices* — Early Josephson-junction data contains the quasiparticle density, recoverable from the subgap current. *Mech:* the subgap current is proportional to the quasiparticle density. *Kill:* subgap current inconsistent with a thermal population.

B578 · *precision-metrology* — Retired clock-comparison logs contain the laboratory's tidal signal. *Mech:* the residual's period is the tidal period. *Kill:* no tidal periodicity in the residuals.

B579 · *nuclear-particle* — Old bubble-chamber photographs contain the neutron's charge radius, recoverable from the track's multiple scattering. *Mech:* the scattering's variance is the radiation length. *Kill:* variance inconsistent with the known radiation length.

B580 · *astrophysics* — Photographic plate archives contain the light echoes of historical transients, recoverable from the plate's grain noise. *Mech:* the echo's position is recoverable from the digitised plate. *Kill:* no echo recoverable from a plate with a known transient.

B581 · *planetary* — Early spacecraft magnetometer data contains the solar wind's density, recoverable because the spacecraft's attitude was logged. *Mech:* the field's direction is set by the attitude. *Kill:* the recovered density inconsistent with the contemporaneous monitor.

B582 · *geophysics* — Old leveling surveys contain the coseismic strain of historical earthquakes, recoverable because the benchmarks' locations are known. *Mech:* the elevation change is the strain's integral. *Kill:* elevation change inconsistent with the historical record.

B583 · *atmosphere* — Early radiosonde data contains the instrument's radiation bias, recoverable because the launch times are logged. *Mech:* the bias's magnitude depends on the solar angle. *Kill:* bias independent of the logged launch time.

B584 · *ocean-ice* — Whaling logbooks contain the sea-ice edge, recoverable because the positions were recorded. *Mech:* the ships' locations track the ice's limit. *Kill:* recovered edge inconsistent with the contemporary charts.

B585 · *hydrology-soil* — Old irrigation records contain the soil's infiltration rate, recoverable because the application volumes were logged. *Mech:* the volume needed to pond is the infiltration. *Kill:* recovered rate inconsistent with a modern measurement.

B586 · *microbiology* — Archived strain collections contain the pre-antibiotic resistance baseline, recoverable from the freeze-dried stocks. *Mech:* the stocks' genomes predate the selection. *Kill:* the stocks carrying modern resistance genes.

B587 · *plant-agriculture* — Old variety trial data contains the genotype-by-environment variance, recoverable because the plots' locations are known. *Mech:* the variance components are in the residuals. *Kill:* residuals inconsistent with any spatial model.

B588 · *neuroscience* — Early microelectrode data contains the local field's spectrum, recoverable because the filters were documented. *Mech:* the filter's inverse is recoverable. *Kill:* spectrum inconsistent with the documented filter.

B589 · *immunology* — Old sera collections contain the antigenic drift of past epidemics, recoverable by testing against modern strains. *Mech:* the sera's neutralisation is the drift's history. *Kill:* sera neutralising modern strains equally.

B590 · *developmental-biology* — Old time-lapse films contain the cell lineage's timing, recoverable because the frame rate is known. *Mech:* the lineage's timing is in the frame sequence. *Kill:* lineage timing inconsistent across films.

B591 · *ecology-evolution* — Old naturalists' journals contain the phenology's shift, recoverable because the dates are recorded. *Mech:* the first-flowering dates are the phenology. *Kill:* dates inconsistent with the contemporaneous herbarium.

B592 · *medicine-diagnostics* — Old trial data contains the placebo response's structure, recoverable because the randomisation is documented. *Mech:* the placebo's variance is separable from the drug's. *Kill:* placebo variance inconsistent with the documented design.

B593 · *pharmacology* — Old pharmacokinetic data contains the enterohepatic recirculation, recoverable from the secondary peaks. *Mech:* the peaks' timing is the recirculation's period. *Kill:* no secondary peaks in the raw data.

B594 · *food-science* — Old canning records contain the thermal-death time, recoverable because the retort's profile is logged. *Mech:* the profile's integral is the lethality. *Kill:* lethality inconsistent with the logged profile.

B595 · *materials-failure* — Old fatigue data contains the crack-closure effect, recoverable because the load ratios were recorded. *Mech:* the closure's contribution is in the R-ratio dependence. *Kill:* no R-ratio dependence in the data.

B596 · *structural-civil* — Old bridge inspection photographs contain the crack's growth rate, recoverable because the dates are stamped. *Mech:* the crack's length is measurable from the photographs. *Kill:* growth inconsistent with the stamped dates.

B597 · *energy-systems* — Old cell-testing data contains the lithium plating onset, recoverable from the voltage's relaxation. *Mech:* the relaxation's shape is the plating's signature. *Kill:* relaxation identical for cells with and without plating.

B598 · *manufacturing* — Old process logs contain the machine's thermal error, recoverable because the probe's measurements are recorded. *Mech:* the error's time constant is in the logs. *Kill:* error inconsistent with the probe's record.

B599 · *acoustics-vibration* — Old concert-hall recordings contain the hall's absorption, recoverable because the orchestra's repertoire is known. *Mech:* the reverberation is in the recording. *Kill:* reverberation inconsistent across the repertoire.

B600 · *signal-information* — Old tape recordings contain the recorder's wow and flutter, recoverable from the recorded tone. *Mech:* the tone's frequency modulation is the flutter. *Kill:* modulation inconsistent with the recorder's specification.

Discovery07 — The Black Swan Grid, operators 21–25

Operator 21 — Reverse engineering the pathology

Deliberately break the device or material and read the failure as a measurement of the property you could not measure when it worked.

B601 · *condensed-matter* — Delaminating a film measures its interface toughness, a quantity no intact-sample test reaches. *Mech:* the buckle's wavelength is set by the interface energy. *Kill:* buckle wavelength independent of the measured interface energy.

B602 · *soft-matter* — Crushing a gel measures its strand persistence length. *Mech:* the collapse pressure is set by the strand's bending stiffness. *Kill:* collapse pressure independent of the measured stiffness.

B603 · *electrochemistry* — Shorting a cell measures the separator's pore-size tail. *Mech:* the short's onset current is set by the largest pore. *Kill:* onset current independent of the measured pore tail.

B604 · *catalysis* — Poisoning a catalyst measures its site distribution. *Mech:* the poison's uptake versus activity loss maps the site's strength distribution. *Kill:* activity loss independent of the poison's uptake.

B605 · *photochemistry* — Photobleaching a dye measures its triplet lifetime. *Mech:* the bleach rate under constant illumination is set by the triplet's steady-state population. *Kill:* bleach rate independent of the measured triplet lifetime.

B606 · *ultrafast* — Damaging a mirror measures its coating's absorption. *Mech:* the damage threshold is set by the absorbed fluence. *Kill:* threshold independent of the measured absorption.

B607 · *quantum-devices* — Overdriving a qubit measures its junction's critical current. *Mech:* the drive-induced switching is set by the current's margin. *Kill:* switching independent of the measured critical current.

B608 · *precision-metrology* — Unlocking a clock measures its cavity's drift. *Mech:* the free-running frequency walks with the cavity. *Kill:* walk independent of the measured cavity drift.

B609 · *nuclear-particle* — Overbiasing a detector measures its depletion voltage. *Mech:* the breakdown's onset is set by the depletion. *Kill:* onset independent of the measured depletion.

B610 · *astrophysics* — Saturating a detector measures its full-well depth. *Mech:* the bleed's onset is the well depth. *Kill:* onset independent of the measured depth.

B611 · *planetary* — Crashing a probe measures the surface's bearing strength. *Mech:* the impact's deceleration is the strength. *Kill:* deceleration independent of the measured strength.

B612 · *geophysics* — Fracturing a rock in the lab measures its in-situ stress. *Mech:* the fracture's orientation is set by the stress. *Kill:* orientation independent of the measured stress.

B613 · *atmosphere* — Fouling a sensor measures the aerosol's composition. *Mech:* the fouling rate is set by the deposition velocity. *Kill:* fouling independent of the measured composition.

B614 · *ocean-ice* — Breaking an ice core measures its brine permeability. *Mech:* the break's pattern follows the brine network. *Kill:* pattern independent of the measured permeability.

B615 · *hydrology-soil* — Eroding a soil column measures its aggregate stability. *Mech:* the erosion's onset is set by the aggregate's strength. *Kill:* onset independent of the measured stability.

B616 · *microbiology* — Lysozyme-treating a biofilm measures its matrix composition. *Mech:* the lysis's extent is set by the matrix's polymer content. *Kill:* lysis independent of the measured content.

B617 · *plant-agriculture* — Droughting a plant measures its rooting depth. *Mech:* the wilting's onset is set by the depth's water access. *Kill:* onset independent of the measured depth.

B618 · *neuroscience* — Killing a neuron measures its synaptic contribution. *Mech:* the network's response change is the cell's contribution. *Kill:* no response change after ablation.

B619 · *immunology* — Depleting a cell type measures its regulatory contribution. *Mech:* the response's change is the contribution. *Kill:* no change after depletion.

B620 · *developmental-biology* — Ablating a cell measures its inductive contribution. *Mech:* the neighbour's fate change is the contribution. *Kill:* no fate change after ablation.

B621 · *ecology-evolution* — Removing a predator measures its functional response. *Mech:* the prey's release is the response. *Kill:* no prey release after removal.

B622 · *medicine-diagnostics* — Withdrawing a drug measures its effect size. *Mech:* the rebound's magnitude is the effect. *Kill:* no rebound after withdrawal.

B623 · *pharmacology* — Saturating a transporter measures its capacity. *Mech:* the plateau's height is the capacity. *Kill:* no plateau at high dose.

B624 · *food-science* — Freeze-thawing a product measures its ice's recrystallisation. *Mech:* the drip loss is the recrystallisation's extent. *Kill:* drip loss independent of the cycle count.

B625 · *materials-failure* — Overloading a component measures its residual stress. *Mech:* the deformation's asymmetry is the residual field. *Kill:* asymmetry independent of the measured stress.

B626 · *structural-civil* — Demolishing a structure measures its actual connection strength. *Mech:* the collapse's sequence is the strength hierarchy. *Kill:* sequence inconsistent with the design.

B627 · *energy-systems* — Overcharging a cell measures its electrolyte's oxidation potential. *Mech:* the gassing's onset is the potential. *Kill:* onset independent of the measured potential.

B628 · *manufacturing* — Breaking a tool measures its edge's toughness. *Mech:* the chipping's threshold is the toughness. *Kill:* threshold independent of the measured toughness.

B629 · *acoustics-vibration* — Driving a panel to failure measures its fatigue limit. *Mech:* the crack's onset is the limit. *Kill:* onset independent of the measured limit.

B630 · *signal-information* — Saturating an amplifier measures its compression point. *Mech:* the gain's roll-off is the compression. *Kill:* roll-off independent of the measured point.

Operator 22 — Adversarial condition

Make the system fail on purpose. The way it fails identifies the mechanism that was working.

B631 · *condensed-matter* — Cooling a superconductor through its transition in a field gradient measures the vortex pinning's anisotropy. *Mech:* the trapped flux's pattern follows the pinning. *Kill:* pattern isotropic in a sample with known anisotropic pinning.

B632 · *soft-matter* — Shearing a gel past its yield measures its structural recovery time. *Mech:* the recovery's kinetics are the network's reformation. *Kill:* recovery independent of the shear's magnitude.

B633 · *electrochemistry* — Cycling a cell at high rate measures its electrode's tortuosity. *Mech:* the rate capability is set by the tortuosity. *Kill:* capability independent of the measured tortuosity.

B634 · *catalysis* — Starving a reactor of reactant measures the catalyst's oxygen storage. *Mech:* the activity's decay is the storage's depletion. *Kill:* decay independent of the measured storage.

B635 · *photochemistry* — Quenching a reaction with a radical trap measures the radical's lifetime. *Mech:* the product's suppression is the trap's competition. *Kill:* suppression independent of the trap's concentration.

B636 · *ultrafast* — Chirping a pulse to its transform limit measures the medium's dispersion. *Mech:* the required chirp is the dispersion's integral. *Kill:* required chirp independent of the measured dispersion.

B637 · *quantum-devices* — Driving a qubit off-resonance measures its anharmonicity. *Mech:* the Rabi frequency's dependence on detuning. *Kill:* dependence inconsistent with the measured anharmonicity.

B638 · *precision-metrology* — Modulating a clock's frequency measures its servo's gain. *Mech:* the response's amplitude is the gain. *Kill:* amplitude independent of the measured gain.

B639 · *nuclear-particle* — Overloading a detector measures its pile-up rejection. *Mech:* the spectrum's distortion is the rejection's efficiency. *Kill:* distortion independent of the measured rejection.

B640 · *astrophysics* — Defocusing a telescope measures its pixel response. *Mech:* the donut's structure is the pixel's footprint. *Kill:* structure independent of the measured footprint.

B641 · *planetary* — Overexposing an imager measures its charge diffusion. *Mech:* the bloom's extent is the diffusion length. *Kill:* extent independent of the measured length.

B642 · *geophysics* — Clipping a seismogram measures the instrument's full scale. *Mech:* the clipped amplitude is the scale. *Kill:* scale inconsistent with the specification.

B643 · *atmosphere* — Saturating a hygrometer measures its response time. *Mech:* the saturation's recovery is the time constant. *Kill:* recovery independent of the measured constant.

B644 · *ocean-ice* — Freezing a sensor into ice measures its thermal coupling. *Mech:* the response's lag is the coupling. *Kill:* lag independent of the measured coupling.

B645 · *hydrology-soil* — Flooding a soil sensor measures its air-entry value. *Mech:* the reading's plateau is the air entry. *Kill:* plateau independent of the measured value.

B646 · *microbiology* — Starving a culture measures its maintenance coefficient. *Mech:* the decay's rate is the maintenance. *Kill:* rate independent of the measured coefficient.

B647 · *plant-agriculture* — Flooding a root system measures its aerenchyma. *Mech:* the survival's duration is the aerenchyma's capacity. *Kill:* survival independent of the measured capacity.

B648 · *neuroscience* — Blocking inhibition measures the network's excitation balance. *Mech:* the runaway's onset is the balance. *Kill:* onset independent of the measured balance.

B649 · *immunology* — Blocking a checkpoint measures the response's reserve. *Mech:* the response's increase is the reserve. *Kill:* no increase after blockade.

B650 · *developmental-biology* — Removing a tissue's neighbour measures its self-organisation capacity. *Mech:* the remaining tissue's pattern is the capacity. *Kill:* no pattern after removal.

B651 · *ecology-evolution* — Removing a keystone measures the community's redundancy. *Mech:* the collapse's extent is the redundancy's limit. *Kill:* no collapse after removal.

B652 · *medicine-diagnostics* — Withholding treatment measures the disease's natural history. *Mech:* the untreated course is the history. *Kill:* course inconsistent with the historical record.

B653 · *pharmacology* — Blocking a metabolic pathway measures the drug's alternate clearance. *Mech:* the exposure's increase is the alternate route. *Kill:* no exposure change after blockade.

B654 · *food-science* — Abusing a product's storage measures its barrier's limit. *Mech:* the quality's decay is the barrier's permeability. *Kill:* decay independent of the measured permeability.

B655 · *materials-failure* — Overloading a joint measures its clamp's preload. *Mech:* the slip's onset is the preload. *Kill:* onset independent of the measured preload.

B656 · *structural-civil* — Shaking a structure to its limit measures its ductility. *Mech:* the drift's capacity is the ductility. *Kill:* capacity independent of the measured ductility.

B657 · *energy-systems* — Fast-charging to failure measures the cell's plating margin. *Mech:* the failure's onset is the margin. *Kill:* onset independent of the measured margin.

B658 · *manufacturing* — Cutting dry measures the coolant's contribution. *Mech:* the wear's increase is the coolant's benefit. *Kill:* no wear increase without coolant.

B659 · *acoustics-vibration* — Driving a room to clipping measures its modal overlap. *Mech:* the distortion's onset is the overlap. *Kill:* onset independent of the measured overlap.

B660 · *signal-information* — Injecting worst-case interference measures the receiver's dynamic range. *Mech:* the desensitisation is the range. *Kill:* desensitisation independent of the measured range.

Operator 23 — Extreme environment

Go where the standard model has no business working, and find out which part of it survives.

B661 · *condensed-matter* — At megabar pressure, the phonon's contribution to thermal conductivity saturates because the lattice becomes stiff enough that anharmonicity dominates. *Mech:* the conductivity's pressure dependence changes sign at the point where anharmonic scattering overtakes the phonon population. *Kill:* conductivity monotonic in pressure across the predicted point.

B662 · *soft-matter* — At cryogenic temperatures, a glassy polymer's yield stress becomes temperature-independent because tunnelling dominates. *Mech:* the yield's activation energy saturates at the tunnelling scale. *Kill:* yield stress continuing to fall to zero temperature.

B663 · *electrochemistry* — At high pressure, the double layer's capacitance becomes pressure-independent because the solvent's compressibility saturates. *Mech:* the capacitance is set by the solvent's density. *Kill:* capacitance continuing to change with pressure.

B664 · *catalysis* — At supercritical conditions, the catalyst's activity becomes independent of the support because the solvent's density homogenises the local environment. *Mech:* the support's confinement vanishes at high density. *Kill:* activity still support-dependent above the critical density.

B665 · *photochemistry* — At very high intensity, the quantum yield becomes intensity-independent because the annihilation and generation balance. *Mech:* the yield saturates at a value set by the annihilation coefficient. *Kill:* yield continuing to fall with intensity.

B666 · *ultrafast* — At relativistic intensity, the plasma mirror's reflectivity becomes independent of the target material. *Mech:* the reflection is set by the plasma's density gradient. *Kill:* reflectivity still material-dependent at the predicted intensity.

B667 · *quantum-devices* — At millikelvin temperatures, the qubit's dephasing becomes temperature-independent because the noise is dominated by a single two-level system. *Mech:* the total-system's occupation freezes out. *Kill:* dephasing continuing to fall below the predicted temperature.

B668 · *precision-metrology* — At very high atomic density, the clock's frequency shift becomes density-independent because the collisional and light-shift terms cancel. *Mech:* the two shifts have opposite signs and cross. *Kill:* shift monotonic in density.

B669 · *nuclear-particle* — At very high rate, the detector's resolution improves because the space charge focuses the avalanche. *Mech:* the field's self-focusing reduces the gain's variance. *Kill:* resolution monotonic with rate.

B670 · *astrophysics* — At very high redshift, the metallicity floor becomes independent of the galaxy's mass because the intergalactic medium's enrichment dominates. *Mech:* the floor is set by the IGM's background. *Kill:* floor still mass-dependent at the highest redshift.

B671 · *planetary* — At very high surface temperature, the rock's thermal conductivity becomes independent of composition because radiation dominates. *Mech:* the radiative contribution overwhelms the lattice. *Kill:* conductivity still composition-dependent at the predicted temperature.

B672 · *geophysics* — At very high strain rate, the fault's friction becomes rate-independent because the asperities melt. *Mech:* the melt removes the rate dependence. *Kill:* rate dependence persisting at the highest rates.

B673 · *atmosphere* — At very high supersaturation, the droplet's growth becomes independent of the aerosol's composition. *Mech:* the growth is limited by the vapour's supply. *Kill:* growth still composition-dependent at high supersaturation.

B674 · *ocean-ice* — At very high salinity, the ice's permeability becomes independent of the temperature because the brine's viscosity saturates. *Mech:* the viscosity's Arrhenius dependence flattens. *Kill:* permeability still temperature-dependent at high salinity.

B675 · *hydrology-soil* — At very high suction, the soil's water retention becomes independent of the texture because the adsorption dominates. *Mech:* the surface's adsorption is set by the mineral's surface area. *Kill:* retention still texture-

dependent at high suction.

B676 · *microbiology* — At very high pressure, the growth rate becomes independent of the temperature because the pressure denatures the proteins. *Mech:* the two effects compete. *Kill:* growth still temperature-dependent at the highest pressure.

B677 · *plant-agriculture* — At very high CO_2, the photosynthetic rate becomes independent of the nitrogen supply. *Mech:* the carboxylation's limitation shifts to the electron transport. *Kill:* rate still nitrogen-dependent at high CO_2.

B678 · *neuroscience* — At very high firing rate, the metabolic cost per spike falls because the ion gradients are partially maintained by the activity itself. *Mech:* the activity upregulates the pumps. *Kill:* cost per spike constant across rates.

B679 · *immunology* — At very high antigen dose, the response becomes independent of the affinity because the avidity dominates. *Mech:* the multivalent binding saturates. *Kill:* response still affinity-dependent at high dose.

B680 · *developmental-biology* — At very high temperature, the developmental rate becomes independent of the genotype because the proteins are at their stability limit. *Mech:* the genotype's variation is swamped by the thermal denaturation. *Kill:* genotype differences persisting at the highest temperature.

B681 · *ecology-evolution* — At very high disturbance, the diversity becomes independent of the productivity. *Mech:* the disturbance resets the competitive hierarchy. *Kill:* diversity still productivity-dependent at high disturbance.

B682 · *medicine-diagnostics* — At very high disease prevalence, the test's predictive value becomes independent of the specificity. *Mech:* the prevalence dominates the calculation. *Kill:* predictive value still specificity-dependent at high prevalence.

B683 · *pharmacology* — At very high dose, the clearance becomes independent of the blood flow because the enzyme saturates. *Mech:* the capacity limits the extraction. *Kill:* clearance still flow-dependent at high dose.

B684 · *food-science* — At very low water activity, the reaction rate becomes independent of the temperature because diffusion stops. *Mech:* the glassy matrix freezes the reactants. *Kill:* rate still temperature-dependent below the glass transition.

B685 · *materials-failure* — At very high strain rate, the fracture toughness becomes independent of the microstructure. *Mech:* the crack outruns the plasticity. *Kill:* toughness still microstructure-dependent at high rate.

B686 · *structural-civil* — At very high loading, the structure's damping becomes independent of the connections because the material's own damping dominates. *Mech:* the joints' slip saturates. *Kill:* damping still connection-dependent at high load.

B687 · *energy-systems* — At very high C-rate, the cell's capacity becomes independent of the electrode's thickness. *Mech:* the reaction is confined to the separator-facing surface. *Kill:* capacity still thickness-dependent at high rate.

B688 · *manufacturing* — At very high scan speed, the porosity becomes independent of the laser power. *Mech:* the melt pool's depth saturates at the powder layer. *Kill:* porosity still power-dependent at high speed.

B689 · *acoustics-vibration* — At very high intensity, the absorption coefficient becomes independent of the material because the nonlinearity dominates. *Mech:* the shock formation absorbs by a different mechanism. *Kill:* coefficient still material-dependent at high intensity.

B690 · *signal-information* — At very high SNR, the capacity becomes independent of the coding scheme because the shaping gain saturates. *Mech:* the gap to capacity is bounded. *Kill:* a scheme gaining more than the shaping bound above the predicted SNR.

Operator 24 — Minimal system

Reduce to the simplest possible case. If the effect survives, the mechanism is simpler than believed; if it vanishes, the complexity was the cause.

B691 · *condensed-matter* — A single-crystal, single-domain, strain-free sample shows no Kondo-like resistivity minimum. *Mech:* the minimum requires disorder, not the Kondo effect. *Kill:* a minimum persisting in a sample with measured disorder below the detection limit.

B692 · *soft-matter* — A two-particle system shows the same yielding as a bulk gel. *Mech:* yielding is a pairwise bond-breaking event. *Kill:* no yielding in the two-particle system.

B693 · *electrochemistry* — A single-crystal electrode with one exposed facet shows the same Tafel slope as a polycrystal. *Mech:* the slope is set by the mechanism, not the facet distribution. *Kill:* facet-dependent slopes across the series.

B694 · *catalysis* — A single-atom catalyst shows the same TOF as a nanoparticle. *Mech:* the active site is the same. *Kill:* TOF differing by more than the site-count uncertainty.

B695 · *photochemistry* — A single molecule shows the same quantum yield as an ensemble. *Mech:* the yield is intrinsic. *Kill:* single-molecule yields differing by more than the ensemble's spread.

B696 · *ultrafast* — A single-cycle pulse produces the same transient as a multi-cycle one at equal fluence. *Mech:* the response is set by the absorbed energy, not the pulse's shape. *Kill:* transients differing at equal fluence.

B697 · *quantum-devices* — A single-junction qubit shows the same coherence as a multi-junction one. *Mech:* the junction's noise is not the limit. *Kill:* coherence differing by more than the junction count's expected contribution.

B698 · *precision-metrology* — A single-ion clock shows the same stability per ion as a multi-ion one. *Mech:* the ions are independent. *Kill:* stability per ion worse in the multi-ion case.

B699 · *nuclear-particle* — A single-photoelectron signal shows the same resolution as the full-spectrum one. *Mech:* the resolution is photostatistical. *Kill:* resolution differing beyond the photostatistical prediction.

B700 · *astrophysics* — A single-star system shows the same planet frequency as a binary. *Mech:* the disc's fragmentation is independent of the companion. *Kill:* frequency differing by more than the detection bias.

B701 · *planetary* — A single-crater surface shows the same age as a multi-crater one. *Mech:* the production function is stationary. *Kill:* ages differing systematically with crater count.

B702 · *geophysics* — A single-asperity contact shows the same friction law as a fault. *Mech:* the law is scale-independent. *Kill:* the law differing between the two.

B703 · *atmosphere* — A single-cloud system shows the same albedo susceptibility as a field of clouds. *Mech:* the susceptibility is a single-cloud property. *Kill:* field susceptibility differing by more than the overlap's contribution.

B704 · *ocean-ice* — A single brine channel shows the same permeability as the network. *Mech:* the network's permeability is set by the channel's. *Kill:* network permeability differing by more than the percolation factor.

B705 · *hydrology-soil* — A single-pore model shows the same retention curve as the soil. *Mech:* the curve is a pore-size integral. *Kill:* the curve not reproducible from the measured pore distribution.

B706 · *microbiology* — A single cell shows the same growth rate as the population. *Mech:* the rate is intrinsic. *Kill:* single-cell rates differing by more than the population's spread.

B707 · *plant-agriculture* — A single leaf shows the same water-use efficiency as the canopy. *Mech:* the efficiency is set by the leaf's gas exchange. *Kill:* canopy efficiency differing by more than the boundary-layer correction.

B708 · *neuroscience* — A single synapse shows the same plasticity rule as the network. *Mech:* the rule is synaptic. *Kill:* network plasticity differing by more than the connectivity's contribution.

B709 · *immunology* — A single B cell shows the same affinity maturation as the germinal centre. *Mech:* the maturation is cell-autonomous. *Kill:* maturation differing by more than the selection's contribution.

B710 · *developmental-biology* — A single cell in isolation shows the same fate as in the embryo. *Mech:* the fate is cell-autonomous. *Kill:* fate differing in isolation.

B711 · *ecology-evolution* — A single species in a microcosm shows the same dynamics as the community. *Mech:* the dynamics are set by the species' own traits. *Kill:* dynamics differing by more than the interaction's contribution.

B712 · *medicine-diagnostics* — A single-analyte sample shows the same assay performance as a clinical sample. *Mech:* the matrix's interference is negligible. *Kill:* performance differing in the clinical matrix.

B713 · *pharmacology* — A single-enzyme system shows the same clearance as the whole organ. *Mech:* one enzyme dominates. *Kill:* clearance differing by more than the enzyme's fraction.

B714 · *food-science* — A single-component model food shows the same texture as the real product. *Mech:* the texture is set by the dominant component. *Kill:* texture differing by more than the minor components' contribution.

B715 · *materials-failure* — A single-crystal specimen shows the same fatigue limit as the polycrystal. *Mech:* the limit is set by the slip's reversibility. *Kill:* limits differing by more than the grain-boundary contribution.

B716 · *structural-civil* — A single-bay frame shows the same period as the full building. *Mech:* the period is set by the bay's stiffness. *Kill:* period differing by more than the bay count's contribution.

B717 · *energy-systems* — A single-layer electrode shows the same rate capability as the composite. *Mech:* the capability is set by the active material. *Kill:* capability differing by more than the additive's contribution.

B718 · *manufacturing* — A single-track scan shows the same porosity as the bulk build. *Mech:* the porosity is set by the track's geometry. *Kill:* porosity differing by more than the overlap's contribution.

B719 · *acoustics-vibration* — A single-panel measurement shows the same transmission as the full partition. *Mech:* the transmission is set by the panel. *Kill:* transmission differing by more than the flanking's contribution.

B720 · *signal-information* — A single-tap channel shows the same capacity as the multipath one. *Mech:* the capacity is set by the SNR. *Kill:* capacity differing by more than the diversity's contribution.

Operator 25 — Contradiction mining

Two published results cannot both be right. The contradiction's structure identifies which assumption is shared and wrong.

B721 · *condensed-matter* — Two measurements of the same material's thermal conductivity differ by 3×, and both are right because they measure different tensor components with the same label. *Mech:* the anisotropy is not reported. *Kill:* anisotropy measured and found insufficient to explain the discrepancy.

B722 · *soft-matter* — Two measurements of the same polymer's viscosity differ by an order of magnitude, and both are right because one is at a different solvent quality. *Mech:* the solvent's quality changes the hydrodynamic radius. *Kill:* solvent quality matched and the discrepancy persisting.

B723 · *electrochemistry* — Two measurements of the same catalyst's overpotential differ, and both are right because one is iR-corrected and one is not. *Mech:* the correction's magnitude is the discrepancy. *Kill:* discrepancy persisting after matched correction.

B724 · *catalysis* — Two measurements of the same catalyst's selectivity differ, and both are right because one is at a different conversion. *Mech:* the selectivity's conversion dependence. *Kill:* discrepancy persisting at matched conversion.

B725 · *photochemistry* — Two measurements of the same dye's quantum yield differ, and both are right because one used an integrating sphere and one did not. *Mech:* the sphere captures the scattered light. *Kill:* discrepancy persisting with matched collection.

B726 · *ultrafast* — Two measurements of the same relaxation differ, and both are right because one is at a different excitation density. *Mech:* the Auger contribution. *Kill:* discrepancy persisting at matched density.

B727 · *quantum-devices* — Two measurements of the same qubit's coherence differ, and both are right because one includes the readout error. *Mech:* the readout's backaction. *Kill:* discrepancy persisting with matched readout.

B728 · *precision-metrology* — Two measurements of the same clock's stability differ, and both are right because one uses overlapping and one non-overlapping Allan deviation. *Mech:* the estimator's bias. *Kill:* discrepancy persisting with matched estimator.

B729 · *nuclear-particle* — Two measurements of the same cross section differ, and both are right because one includes the radiative correction. *Mech:* the correction's scheme dependence. *Kill:* discrepancy persisting with matched scheme.

B730 · *astrophysics* — Two measurements of the same galaxy's mass differ, and both are right because one is dynamical and one is lensing, and they measure different mass components. *Mech:* the baryon fraction differs. *Kill:* the two agreeing after baryon correction.

B731 · *planetary* — Two measurements of the same crater's age differ, and both are right because one counts craters and one counts radiation dose. *Mech:* the production functions differ. *Kill:* the two agreeing after cross-calibration.

B732 · *geophysics* — Two measurements of the same fault's slip rate differ, and both are right because one averages over the seismic cycle. *Mech:* the geodetic and geologic rates differ within a cycle. *Kill:* the two agreeing at all timescales.

B733 · *atmosphere* — Two measurements of the same aerosol's forcing differ, and both are right because one is at the top and one at the surface. *Mech:* the atmospheric absorption between them. *Kill:* the two agreeing after column correction.

B734 · *ocean-ice* — Two measurements of the same ice's thickness differ, and both are right because one includes the snow. *Mech:* the freeboard conversion. *Kill:* the two agreeing after snow correction.

B735 · *hydrology-soil* — Two measurements of the same catchment's discharge differ, and both are right because one includes groundwater. *Mech:* the baseflow's separation. *Kill:* the two agreeing after separation.

B736 · *microbiology* — Two measurements of the same strain's growth rate differ, and both are right because one is at a different oxygen tension. *Mech:* the metabolic shift. *Kill:* the two agreeing at matched oxygen.

B737 · *plant-agriculture* — Two measurements of the same variety's yield differ, and both are right because one is at a different planting density. *Mech:* the density's effect. *Kill:* the two agreeing at matched density.

B738 · *neuroscience* — Two measurements of the same neuron's firing differ, and both are right because one is intracellular and one extracellular. *Mech:* the extracellular's filtering. *Kill:* the two agreeing after deconvolution.

B739 · *immunology* — Two measurements of the same antibody's affinity differ, and both are right because one is in solution and one on a surface. *Mech:* the surface's avidity. *Kill:* the two agreeing with a monovalent surface.

B740 · *developmental-biology* — Two measurements of the same tissue's growth differ, and both are right because one is in vivo and one in culture. *Mech:* the culture's stiffness. *Kill:* the two agreeing at matched stiffness.

B741 · *ecology-evolution* — Two measurements of the same species' dispersal differ, and both are right because one is genetic and one is observational. *Mech:* the genetic includes rare long-distance events. *Kill:* the two agreeing at matched timescale.

B742 · *medicine-diagnostics* — Two measurements of the same test's sensitivity differ, and both are right because one uses a different reference standard. *Mech:* the reference's imperfection. *Kill:* the two agreeing with a perfect reference.

B743 · *pharmacology* — Two measurements of the same drug's half-life differ, and both are right because one is at a different dose. *Mech:* the non-linearity. *Kill:* the two agreeing at matched dose.

B744 · *food-science* — Two measurements of the same product's shelf life differ, and both are right because one is at a different humidity. *Mech:* the moisture's effect. *Kill:* the two agreeing at matched humidity.

B745 · *materials-failure* — Two measurements of the same alloy's toughness differ, and both are right because one is at a different constraint. *Mech:* the specimen's thickness. *Kill:* the two agreeing at matched constraint.

B746 · *structural-civil* — Two measurements of the same building's period differ, and both are right because one is ambient and one is forced. *Mech:* the amplitude dependence. *Kill:* the two agreeing at matched amplitude.

B747 · *energy-systems* — Two measurements of the same cell's capacity differ, and both are right because one is at a different temperature. *Mech:* the temperature's effect. *Kill:* the two agreeing at matched temperature.

B748 · *manufacturing* — Two measurements of the same part's tolerance differ, and both are right because one is at a different temperature. *Mech:* the thermal expansion. *Kill:* the two agreeing at matched temperature.

B749 · *acoustics-vibration* — Two measurements of the same room's absorption differ, and both are right because one is at a different humidity. *Mech:* the air's absorption. *Kill:* the two agreeing at matched humidity.

B750 · *signal-information* — Two measurements of the same channel's capacity differ, and both are right because one uses a different input distribution. *Mech:* the capacity is a maximum over distributions. *Kill:* the two agreeing at the optimal distribution.

Discovery07 — The Black Swan Grid, operators 26–30

Operator 26 — Hidden conservation

There is a quantity that is conserved but not measured. Its conservation forces a relation between things that look independent.

B751 · *condensed-matter* — The total momentum of the electron–phonon system is conserved, so the thermal and electrical resistivities must satisfy a relation tighter than Wiedemann–Franz in the phonon-drag regime. *Mech:* momentum conservation couples the two currents. *Kill:* the relation violated in a clean metal at low temperature.

B752 · *soft-matter* — The total number of network strands is conserved, so the modulus and the fracture strain are not independent. *Mech:* strand scission trades one for the other. *Kill:* modulus and fracture strain varying independently.

B753 · *electrochemistry* — The total ionic charge is conserved, so the cell's capacity and its impedance must satisfy a sum rule. *Mech:* the impedance's low-frequency limit is the inverse of the stored charge's derivative. *Kill:* the rule violated across a chemistry series.

B754 · *catalysis* — The total number of active sites is conserved, so the TOF and the site density cannot both be varied freely. *Mech:* any apparent variation is a site-count artefact. *Kill:* TOF and site density varying independently with independent measurements.

B755 · *photochemistry* — The total photon number is conserved, so the quantum yield and the absorption cannot be independently optimised. *Mech:* the product is bounded by the photon budget. *Kill:* a system exceeding the bound.

B756 · *ultrafast* — The total energy is conserved, so the transient's integrated area fixes the absorbed fluence. *Mech:* the area is the energy's integral. *Kill:* area inconsistent with the measured fluence.

B757 · *quantum-devices* — The total parity is conserved in the qubit's readout, so the readout's error is bounded by the parity's decay. *Mech:* the parity's conservation constrains the assignment. *Kill:* readout error exceeding the parity bound.

B758 · *precision-metrology* — The total atom number is conserved, so the clock's short-term stability and its long-term drift are linked. *Mech:* the atom loss sets both. *Kill:* the two varying independently.

B759 · *nuclear-particle* — The total lepton number is conserved, so the detector's background and its signal efficiency are linked. *Mech:* the same interaction produces both. *Kill:* the two varying independently across calibrations.

B760 · *astrophysics* — The total baryon number is conserved, so the galaxy's stellar mass and its gas mass must sum to the cosmic value. *Mech:* the sum is fixed. *Kill:* the sum varying with the measurement method.

B761 · *planetary* — The total angular momentum is conserved, so the planet's spin and its orbit are linked. *Mech:* the tidal transfer. *Kill:* the two evolving independently.

B762 · *geophysics* — The total moment is conserved, so the seismic and aseismic slip must sum to the plate motion. *Mech:* the budget. *Kill:* the sum not matching the plate rate.

B763 · *atmosphere* — The total water is conserved, so the precipitation and the evaporation must balance on the annual mean. *Mech:* the budget. *Kill:* a persistent imbalance at the global scale.

B764 · *ocean-ice* — The total salt is conserved, so the ice's salinity and the ocean's must trade. *Mech:* the rejection. *Kill:* the two varying independently.

B765 · *hydrology-soil* — The total water is conserved, so the storage and the flux must trade. *Mech:* the budget. *Kill:* the storage changing without a matching flux.

B766 · *microbiology* — The total ATP is conserved, so the growth rate and the maintenance must trade. *Mech:* the budget. *Kill:* the two varying independently.

B767 · *plant-agriculture* — The total carbon is conserved, so the biomass and the respiration must trade. *Mech:* the budget. *Kill:* the biomass increasing without a matching uptake.

B768 · *neuroscience* — The total transmitter is conserved, so the release and the reuptake must trade. *Mech:* the pool. *Kill:* the two varying independently.

B769 · *immunology* — The total cytokine is conserved, so the free and bound fractions must trade. *Mech:* the binding. *Kill:* the total changing with the assay.

B770 · *developmental-biology* — The total cell number is conserved, so the proliferation and the death must trade. *Mech:* the balance. *Kill:* the number increasing without proliferation.

B771 · *ecology-evolution* — The total energy is conserved, so the trophic transfer and the storage must trade. *Mech:* the budget. *Kill:* the storage increasing without a matching input.

B772 · *medicine-diagnostics* — The total drug is conserved, so the plasma and tissue concentrations must trade. *Mech:* the mass balance. *Kill:* the two varying independently.

B773 · *pharmacology* — The total dose is conserved, so the absorbed and excreted must trade. *Mech:* the balance. *Kill:* the excretion exceeding the dose.

B774 · *food-science* — The total water is conserved, so the drying and the rehydration must trade. *Mech:* the balance. *Kill:* the rehydration exceeding the original.

B775 · *materials-failure* — The total volume is conserved in wear, so the debris and the track must trade. *Mech:* the balance. *Kill:* the track volume exceeding the wear volume.

B776 · *structural-civil* — The total energy is conserved, so the input and the dissipated must trade. *Mech:* the balance. *Kill:* the dissipated exceeding the input.

B777 · *energy-systems* — The total lithium is conserved, so the capacity and the inventory must trade. *Mech:* the balance. *Kill:* the capacity exceeding the inventory.

B778 · *manufacturing* — The total mass is conserved, so the powder and the part must trade. *Mech:* the balance. *Kill:* the part exceeding the powder.

B779 · *acoustics-vibration* — The total acoustic energy is conserved, so the absorbed and transmitted must trade. *Mech:* the balance. *Kill:* the transmitted exceeding the incident.

B780 · *signal-information* — The total probability is conserved, so the detection and false-alarm rates must trade. *Mech:* the ROC's constraint. *Kill:* the two improved independently at the same threshold.

Operator 27 — Phase and coherence

Something that should have decohered has not, or something that should be coherent is not.

B781 · *condensed-matter* — A macroscopic mechanical oscillator retains coherence across a thermal cycle, which the fluctuation–dissipation theorem forbids. *Mech:* the mode's isolation from the bath is better than the measured Q implies. *Kill:* coherence lost as predicted from the measured Q.

B782 · *soft-matter* — A colloidal crystal retains its registry across a shear cycle, which the melting criterion forbids. *Mech:* the cycle is below the melting strain. *Kill:* registry lost at strains below the predicted threshold.

B783 · *electrochemistry* — An electrode's potential retains phase coherence with an applied oscillation across a redox cycle. *Mech:* the double layer's memory. *Kill:* coherence lost at the predicted cycle time.

B784 · *catalysis* — A catalyst's turnover retains a phase relation with a pulsed feed, which the steady-state assumption forbids. *Mech:* the surface's coverage oscillates. *Kill:* no phase relation at the pulse frequency.

B785 · *photochemistry* — A molecular ensemble retains electronic coherence at room temperature longer than the dephasing time. *Mech:* the ensemble's inhomogeneity is compensated by the environment. *Kill:* coherence decaying at the single-molecule rate.

B786 · *ultrafast* — A phonon mode retains coherence across an electronic excitation, which the anharmonic coupling forbids. *Mech:* the excitation is too fast to couple. *Kill:* coherence lost at the predicted coupling time.

B787 · *quantum-devices* — Two distant qubits retain a phase relation through a shared resonator, which the Purcell effect forbids. *Mech:* the resonator's detuning protects them. *Kill:* the relation lost at the predicted detuning.

B788 · *precision-metrology* — Two independent clocks retain a phase relation after their references are removed. *Mech:* the shared environment imprints a common mode. *Kill:* the relation lost when the environments are isolated.

B789 · *nuclear-particle* — A detector's response retains phase coherence with a pulsed source across a long integration. *Mech:* the source's phase is imprinted on the arrival times. *Kill:* the relation lost at the predicted integration time.

B790 · *astrophysics* — A pulsar retains phase coherence across a glitch, which the timing model forbids. *Mech:* the glitch is a crustal event that does not affect the core's rotation. *Kill:* coherence lost at the glitch.

B791 · *planetary* — A planet's orbital phase retains coherence across a migration event. *Mech:* the migration is adiabatic. *Kill:* the phase scrambled by the migration.

B792 · *geophysics* — A fault's slip retains phase coherence with a tidal forcing across multiple cycles. *Mech:* the tidal stress modulates the nucleation. *Kill:* no phase relation at the tidal period.

B793 · *atmosphere* — A storm system retains phase coherence with the diurnal cycle across multiple days. *Mech:* the surface heating resets the phase each day. *Kill:* the phase drifting freely.

B794 · *ocean-ice* — The ice's annual cycle retains phase coherence with the previous year's. *Mech:* the ocean's heat storage carries the memory. *Kill:* the phase randomised between years.

B795 · *hydrology-soil* — The soil's moisture retains phase coherence with the seasonal cycle across years. *Mech:* the storage integrates the forcing. *Kill:* the phase randomised.

B796 · *microbiology* — A bacterial population retains phase coherence with a periodic nutrient supply. *Mech:* the cells entrain. *Kill:* no entrainment at the predicted period.

B797 · *plant-agriculture* — A plant's stomatal rhythm retains phase coherence with the previous photoperiod. *Mech:* the circadian clock's entrainment. *Kill:* the phase resetting immediately.

B798 · *neuroscience* — A neural population retains phase coherence across a stimulus gap. *Mech:* the oscillation's memory. *Kill:* the phase scrambled by the gap.

B799 · *immunology* — An immune response retains phase coherence with the circadian cycle. *Mech:* the clock's gating. *Kill:* no phase relation at the circadian period.

B800 · *developmental-biology* — A tissue's segmentation clock retains phase coherence across a division. *Mech:* the clock's coupling to the cycle. *Kill:* the phase reset by division.

B801 · *ecology-evolution* — A predator–prey cycle retains phase coherence across a perturbation. *Mech:* the limit cycle's attraction. *Kill:* the phase randomised by the perturbation.

B802 · *medicine-diagnostics* — A biomarker's rhythm retains phase coherence across a treatment. *Mech:* the clock's persistence. *Kill:* the phase reset by treatment.

B803 · *pharmacology* — A drug's effect retains phase coherence with the dosing interval. *Mech:* the receptor's cycling. *Kill:* no phase relation at the dosing period.

B804 · *food-science* — A fermentation retains phase coherence with the initial inoculum's state. *Mech:* the community's initial composition sets the trajectory. *Kill:* the trajectory independent of the inoculum.

B805 · *materials-failure* — A crack's growth retains phase coherence with a cyclic load. *Mech:* the crack tip's plasticity is cycle-locked. *Kill:* the growth decoupled from the cycle.

B806 · *structural-civil* — A structure's modal phase retains coherence across a damage event. *Mech:* the modes are global. *Kill:* the phase scrambled by the damage.

B807 · *energy-systems* — A cell's voltage retains phase coherence with a periodic load. *Mech:* the diffusion's memory. *Kill:* the phase lost at the predicted frequency.

B808 · *manufacturing* — A machine's thermal error retains phase coherence with the production cycle. *Mech:* the cycle's heat load. *Kill:* the error decoupled from the cycle.

B809 · *acoustics-vibration* — A room's modal phase retains coherence across a temperature change. *Mech:* the modes shift but do not randomise. *Kill:* the phase scrambled by the change.

B810 · *signal-information* — A channel's phase retains coherence across a frequency hop. *Mech:* the oscillator's memory. *Kill:* the phase randomised by the hop.

Operator 28 — Topological and global constraints

Local freedom, global rigidity. The constraint forbids something that looks allowed.

B811 · *condensed-matter* — A thin film's defects must sum to zero Burgers vector, so a single dislocation cannot exist and its absence is measurable. *Mech:* the global constraint forces a partner. *Kill:* an isolated dislocation in a bounded film.

B812 · *soft-matter* — A nematic droplet must have total topological charge zero on its surface, so the defect count is fixed. *Mech:* the Poincaré–Hopf theorem. *Kill:* a defect configuration violating the theorem.

B813 · *electrochemistry* — The current's integral over a closed electrode surface must equal the total reaction rate, so a local measurement cannot exceed the global one. *Mech:* the divergence theorem. *Kill:* a local rate exceeding the global.

B814 · *catalysis* — The product's selectivity must sum to one across all products, so a reported selectivity above one is impossible. *Mech:* the mass balance. *Kill:* a reported selectivity above one not explained by an unmeasured product.

B815 · *photochemistry* — The quantum yield must satisfy a sum rule over all channels, so a yield above one requires a chain reaction. *Mech:* the photon budget. *Kill:* a yield above one without a chain mechanism.

B816 · *ultrafast* — The transient's integral must satisfy the Kramers–Kronig relation, so its shape is constrained by its dispersion. *Mech:* causality. *Kill:* a shape violating the relation.

B817 · *quantum-devices* — The qubit's gate set must satisfy the unitarity constraint, so the reported fidelities cannot all be independently high. *Mech:* the process matrix's trace. *Kill:* fidelities violating the constraint.

B818 · *precision-metrology* — The clock's error budget must satisfy the total variance, so the individual terms cannot all be at their limits. *Mech:* the budget's sum. *Kill:* a budget whose terms sum above the measured variance.

B819 · *nuclear-particle* — The branching ratios must sum to one, so a reported set above one is impossible. *Mech:* the conservation. *Kill:* a set above one without an unmeasured channel.

B820 · *astrophysics* — The galaxy's mass must satisfy the virial theorem, so the dynamical and lensing masses are constrained. *Mech:* the virial relation. *Kill:* a system violating the relation.

B821 · *planetary* — The crater's ejecta must satisfy the volume constraint, so the deposit's thickness is bounded. *Mech:* the excavation's volume. *Kill:* a deposit thicker than the bound.

B822 · *geophysics* — The seismic moment tensor must satisfy the double-couple constraint for a shear event, so a non-double-couple component measures the source's complexity. *Mech:* the tensor's trace. *Kill:* a non-double-couple component in a simple event.

B823 · *atmosphere* — The wind field must satisfy the continuity equation, so a measured divergence bounds the vertical velocity. *Mech:* the mass conservation. *Kill:* a divergence inconsistent with the vertical velocity.

B824 · *ocean-ice* — The ice's thickness must satisfy the hydrostatic balance, so the freeboard and draft are constrained. *Mech:* the Archimedes relation. *Kill:* a freeboard inconsistent with the draft.

B825 · *hydrology-soil* — The catchment's water must satisfy the storage constraint, so the outflow is bounded by the inflow plus the storage change. *Mech:* the balance. *Kill:* an outflow exceeding the bound.

B826 · *microbiology* — The cell's composition must satisfy the charge balance, so the intracellular pH and the membrane potential are constrained. *Mech:* the electroneutrality. *Kill:* a composition violating the balance.

B827 · *plant-agriculture* — The canopy's energy must satisfy the surface energy balance, so the latent and sensible fluxes are constrained. *Mech:* the balance. *Kill:* a flux set violating the balance.

B828 · *neuroscience* — The network's firing must satisfy the conservation of synaptic drive, so the total excitation is bounded. *Mech:* the sum. *Kill:* a drive exceeding the bound.

B829 · *immunology* — The repertoire must satisfy the diversity constraint, so the clone sizes sum to the total. *Mech:* the sum. *Kill:* a repertoire violating the sum.

B830 · *developmental-biology* — The tissue's cell count must satisfy the volume constraint, so the density and the size are linked. *Mech:* the packing. *Kill:* a density inconsistent with the size.

B831 · *ecology-evolution* — The food web's flows must satisfy the conservation of energy, so the trophic efficiencies are bounded. *Mech:* the sum. *Kill:* an efficiency exceeding the bound.

B832 · *medicine-diagnostics* — The test's outcomes must satisfy the prevalence constraint, so the sensitivity and specificity are linked to the predictive values. *Mech:* Bayes' theorem. *Kill:* a reported set violating the theorem.

B833 · *pharmacology* — The drug's mass must satisfy the bioavailability constraint, so the intravenous and oral exposures are linked. *Mech:* the fraction absorbed. *Kill:* an oral exposure exceeding the intravenous.

B834 · *food-science* — The product's composition must satisfy the mass balance, so the components sum to 100%. *Mech:* the sum. *Kill:* a composition above 100%.

B835 · *materials-failure* — The fracture's surface energy must satisfy the global energy balance, so the toughness is bounded by the input. *Mech:* the balance. *Kill:* a toughness exceeding the bound.

B836 · *structural-civil* — The frame's equilibrium must satisfy the global equilibrium, so the internal forces are constrained. *Mech:* the statics. *Kill:* a force set violating equilibrium.

B837 · *energy-systems* — The cell's energy must satisfy the conservation, so the charge and discharge energies are linked. *Mech:* the round-trip efficiency. *Kill:* a discharge exceeding the charge.

B838 · *manufacturing* — The part's geometry must satisfy the closure constraint, so the dimensions are constrained. *Mech:* the sum of the tolerances. *Kill:* a geometry violating closure.

B839 · *acoustics-vibration* — The room's modes must satisfy the boundary condition, so the mode frequencies are constrained. *Mech:* the wave equation. *Kill:* a mode frequency violating the boundary.

B840 · *signal-information* — The code's rate must satisfy the Hamming bound, so the distance is constrained. *Mech:* the sphere-packing. *Kill:* a code violating the bound.

Operator 29 — Statistical artefact with a physical signature

An artefact produced by the analysis has structure that looks physical. The structure is the tell.

B841 · *condensed-matter* — The apparent quantum oscillations in a magnetoresistance are a measurement artefact with a period set by the contact spacing, not the Fermi surface. *Mech:* the artefact's frequency depends on the geometry. *Kill:* the frequency invariant to contact geometry.

B842 · *soft-matter* — The apparent shear banding is an artefact of the velocity profile's inversion, with a band width set by the gap. *Mech:* the inversion's resolution. *Kill:* the band width independent of the gap.

B843 · *electrochemistry* — The apparent negative capacitance is an artefact of the potentiostat's phase lag, with a frequency set by the instrument. *Mech:* the lag's frequency is fixed by the electronics. *Kill:* the feature moving with the instrument's bandwidth.

B844 · *catalysis* — The apparent oscillatory rate is an artefact of the mass-flow controller's hunting, with a period set by the controller. *Mech:* the controller's tuning. *Kill:* the oscillation persisting with a different controller.

B845 · *photochemistry* — The apparent blinking is an artefact of the detector's gain drift, with a timescale set by the electronics. *Mech:* the drift's spectrum. *Kill:* the blinking invariant to the detector.

B846 · *ultrafast* — The apparent coherent oscillation is an artefact of the delay stage's pitch, with a period set by the screw. *Mech:* the stage's periodic error. *Kill:* the oscillation persisting with a different stage.

B847 · *quantum-devices* — The apparent coherence revival is an artefact of the pulse generator's clock, with a period set by the clock's drift. *Mech:* the timing's periodic error. *Kill:* the revival invariant to the generator.

B848 · *precision-metrology* — The apparent sidereal variation is an artefact of the laboratory's temperature cycle, with a period set by the HVAC. *Mech:* the cycle's correlation with the sidereal day is coincidental. *Kill:* the variation persisting with the HVAC's period changed.

B849 · *nuclear-particle* — The apparent annual modulation is an artefact of the detector's calibration drift, with a period set by the maintenance schedule. *Mech:* the calibration's seasonal drift. *Kill:* the modulation invariant to the maintenance schedule.

B850 · *astrophysics* — The apparent periodicity in the light curve is an artefact of the observing cadence, with a period set by the scheduling. *Mech:* the window function's aliases. *Kill:* the periodicity invariant to the cadence.

B851 · *planetary* — The apparent surface change is an artefact of the image's registration, with a pattern set by the pointing. *Mech:* the sub-pixel's bias. *Kill:* the change invariant to the registration.

B852 · *geophysics* — The apparent precursory signal is an artefact of the catalogue's reporting, with a pattern set by the network's operations. *Mech:* the reporting's selection. *Kill:* the signal invariant to the network's operations.

B853 · *atmosphere* — The apparent trend is an artefact of the station's relocation, with a step set by the move. *Mech:* the relocation's exposure change. *Kill:* the trend invariant to the relocation.

B854 · *ocean-ice* — The apparent thinning is an artefact of the sensor's drift, with a rate set by the buoy's power budget. *Mech:* the thermistor's drift. *Kill:* the thinning invariant to the sensor's power.

B855 · *hydrology-soil* — The apparent trend is an artefact of the gauge's orifice change, with a step set by the maintenance. *Mech:* the orifice's wear. *Kill:* the trend invariant to the maintenance.

B856 · *microbiology* — The apparent synergy is an artefact of the plate's edge effect, with a pattern set by the layout. *Mech:* the edge's evaporation. *Kill:* the synergy invariant to the layout.

B857 · *plant-agriculture* — The apparent treatment effect is an artefact of the field's drainage, with a pattern set by the slope. *Mech:* the water's redistribution. *Kill:* the effect invariant to the drainage.

B858 · *neuroscience* — The apparent oscillation is an artefact of the reference's impedance, with a frequency set by the electrode. *Mech:* the reference's noise. *Kill:* the oscillation invariant to the reference.

B859 · *immunology* — The apparent cross-reactivity is an artefact of the plate's coating, with a pattern set by the lot. *Mech:* the coating's variability. *Kill:* the cross-reactivity invariant to the lot.

B860 · *developmental-biology* — The apparent phenotype is an artefact of the embryo's orientation, with a pattern set by the mounting. *Mech:* the imaging's projection. *Kill:* the phenotype invariant to the orientation.

B861 · *ecology-evolution* — The apparent trend is an artefact of the observer's effort, with a slope set by the funding. *Mech:* the effort's change. *Kill:* the trend invariant to the effort.

B862 · *medicine-diagnostics* — The apparent improvement is an artefact of the referral pattern, with a step set by the guideline. *Mech:* the case mix's shift. *Kill:* the improvement invariant to the referral.

B863 · *pharmacology* — The apparent interaction is an artefact of the sampling time, with a pattern set by the schedule. *Mech:* the time's confounding. *Kill:* the interaction invariant to the sampling schedule.

B864 · *food-science* — The apparent difference is an artefact of the panel's order, with a pattern set by the serving. *Mech:* the order's effect. *Kill:* the difference invariant to the order.

B865 · *materials-failure* — The apparent scatter is an artefact of the specimen's machining, with a pattern set by the batch. *Mech:* the surface's finish. *Kill:* the scatter invariant to the machining.

B866 · *structural-civil* — The apparent damage is an artefact of the sensor's attachment, with a pattern set by the mounting. *Mech:* the coupling's variability. *Kill:* the damage invariant to the mounting.

B867 · *energy-systems* — The apparent aging is an artefact of the test's temperature, with a rate set by the chamber. *Mech:* the chamber's gradient. *Kill:* the aging invariant to the chamber's temperature.

B868 · *manufacturing* — The apparent defect is an artefact of the inspection's lighting, with a pattern set by the angle. *Mech:* the illumination's direction. *Kill:* the defect invariant to the lighting.

B869 · *acoustics-vibration* — The apparent mode is an artefact of the microphone's position, with a frequency set by the room's corner. *Mech:* the position's coupling. *Kill:* the mode invariant to the position.

B870 · *signal-information* — The apparent structure is an artefact of the window's choice, with a pattern set by the taper. *Mech:* the leakage. *Kill:* the structure invariant to the window.

Operator 30 — The exception that proves the rule

One outlier is the mechanism. The rest of the data is the baseline that makes it visible.

B871 · *condensed-matter* — One crystal in a batch shows anomalous superconductivity, and its anomaly measures the strain sensitivity of the transition. *Mech:* the crystal's mounting strain differs. *Kill:* the anomaly absent when the strain is matched.

B872 · *soft-matter* — One batch of gel is twice as stiff, and its anomaly measures the crosslinker's efficiency. *Mech:* the batch's humidity differs. *Kill:* the anomaly absent at matched humidity.

B873 · *electrochemistry* — One electrode in a series shows an anomalously low overpotential, and its anomaly measures the facet's activity. *Mech:* the facet's exposure differs. *Kill:* the anomaly absent when the facet is matched.

B874 · *catalysis* — One catalyst batch is anomalously active, and its anomaly measures the support's impurity. *Mech:* the impurity's promotion. *Kill:* the anomaly absent when the impurity is matched.

B875 · *photochemistry* — One sample is anomalously bright, and its anomaly measures the aggregate's quantum yield. *Mech:* the aggregation. *Kill:* the anomaly absent when the aggregation is matched.

B876 · *ultrafast* — One run shows an anomalously long relaxation, and its anomaly measures the sample's oxidation. *Mech:* the oxidation's trap. *Kill:* the anomaly absent when the oxidation is matched.

B877 · *quantum-devices* — One qubit is anomalously coherent, and its anomaly measures the substrate's loss tangent. *Mech:* the substrate's quality. *Kill:* the anomaly absent with a matched substrate.

B878 · *precision-metrology* — One run shows an anomalously low drift, and its anomaly measures the cavity's thermal time constant. *Mech:* the run's thermal environment. *Kill:* the anomaly absent at a matched environment.

B879 · *nuclear-particle* — One detector is anomalously quiet, and its anomaly measures the radon's rejection. *Mech:* the shield's seal. *Kill:* the anomaly absent with a matched seal.

B880 · *astrophysics* — One galaxy is anomalously metal-poor, and its anomaly measures the inflow's dilution. *Mech:* the accretion's rate. *Kill:* the anomaly absent at a matched accretion rate.

B881 · *planetary* — One crater is anomalously young, and its anomaly measures the resurfacing's rate. *Mech:* the lava's emplacement. *Kill:* the anomaly absent at a matched resurfacing.

B882 · *geophysics* — One fault is anomalously quiet, and its anomaly measures the creep's fraction. *Mech:* the aseismic slip. *Kill:* the anomaly absent with a matched creep.

B883 · *atmosphere* — One station is anomalously warm, and its anomaly measures the urban heat's advection. *Mech:* the station's exposure. *Kill:* the anomaly absent at a matched exposure.

B884 · *ocean-ice* — One floe is anomalously thin, and its anomaly measures the ocean's heat flux. *Mech:* the upwelling. *Kill:* the anomaly absent with a matched flux.

B885 · *hydrology-soil* — One catchment is anomalously wet, and its anomaly measures the bedrock's leakage. *Mech:* the fracture flow. *Kill:* the anomaly absent with a matched leakage.

B886 · *microbiology* — One strain is anomalously resistant, and its anomaly measures the efflux pump's expression. *Mech:* the pump's copy number. *Kill:* the anomaly absent with a matched expression.

B887 · *plant-agriculture* — One variety is anomalously drought-tolerant, and its anomaly measures the root's hydraulic conductance. *Mech:* the root's anatomy. *Kill:* the anomaly absent with a matched conductance.

B888 · *neuroscience* — One neuron is anomalously fast, and its anomaly measures the axon's myelination. *Mech:* the conduction's velocity. *Kill:* the anomaly absent with matched myelination.

B889 · *immunology* — One donor is anomalously high-titre, and its anomaly measures the cross-reactive memory. *Mech:* the prior exposure. *Kill:* the anomaly absent with a matched exposure.

B890 · *developmental-biology* — One embryo is anomalously large, and its anomaly measures the yolk's contribution. *Mech:* the maternal investment. *Kill:* the anomaly absent with a matched investment.

B891 · *ecology-evolution* — One island is anomalously diverse, and its anomaly measures the immigration's rate. *Mech:* the distance's effect. *Kill:* the anomaly absent at a matched distance.

B892 · *medicine-diagnostics* — One patient is anomalously responsive, and the anomaly measures the drug's target's expression. *Mech:* the expression's variability. *Kill:* the anomaly absent with a matched expression.

B893 · *pharmacology* — One subject is anomalously slow, and the anomaly measures the enzyme's polymorphism. *Mech:* the genotype. *Kill:* the anomaly absent with a matched genotype.

B894 · *food-science* — One batch is anomalously stable, and the anomaly measures the antioxidant's partitioning. *Mech:* the partitioning. *Kill:* the anomaly absent with a matched partitioning.

B895 · *materials-failure* — One specimen is anomalously tough, and the anomaly measures the inclusion's crack-tip shielding. *Mech:* the inclusion's toughness. *Kill:* the anomaly absent with a matched inclusion.

B896 · *structural-civil* — One building is anomalously strong, and the anomaly measures the soil's confinement. *Mech:* the foundation's embedment. *Kill:* the anomaly absent with a matched embedment.

B897 · *energy-systems* — One cell is anomalously long-lived, and the anomaly measures the electrode's prelithiation. *Mech:* the lithium inventory. *Kill:* the anomaly absent with a matched inventory.

B898 · *manufacturing* — One part is anomalously accurate, and the anomaly measures the machine's thermal equilibrium. *Mech:* the soak time. *Kill:* the anomaly absent with a matched soak.

B899 · *acoustics-vibration* — One room is anomalously quiet, and the anomaly measures the leak's absorption. *Mech:* the leakage. *Kill:* the anomaly absent with a matched leak.

B900 · *signal-information* — One link is anomalously reliable, and the anomaly measures the diversity's order. *Mech:* the diversity order. *Kill:* the anomaly absent with a matched order.

Part II — The screened 300

From the 900, ten per operator were advanced. The selection rule is stated and reproducible: each hypothesis was scored on four features — whether the kill test takes a null form ('independent of', 'invariant'), whether the mechanism or the kill test carries a number, whether the claim is comparative rather than descriptive, and whether the kill test is a sweep over a controllable variable. The top ten per operator were kept, so every operator is represented by exactly ten surviving ideas.

Survival tags are assigned by fixed rules, not by editorial judgement: `null-testable` (the kill test is an invariance), `quantitative` (a number appears in the mechanism or the kill), `existing-data` (an archive or log is named), `theorem-backed` (a conservation, symmetry or bound is invoked), `sweepable` (the kill test sweeps a controllable variable), `needs-new-apparatus` (none of the above).

The tags describe *testability*, not truth. Most of these are probably wrong. The point of the tier is that each can be killed cheaply.

Operator 1 — Inversion: the artefact is the signal

Inversion candidates survive when the rejected term is already recorded by the instrument and is calibrated to a physical quantity. Most fail because the artefact is not metrologically stable.

id	field	claim	kill test	tags
B001	condensed-matter	Cryostat thermal drift is a phonon-transport signal, not noise	drift rate independent of sample mounting conductance across a decade	null-testable, quantitative, sweepable
B002	soft-matter	Wall slip in a rheometer is a slip-length measurement with 100 nm resolution	apparent slip independent of gap at fixed stress	null-testable
B007	quantum-devices	Readout crosstalk is a two-qubit coupling meter that beats spectroscopy	crosstalk tail independent of detuning in the predicted power law	null-testable
B011	planetary	Coronagraph stray light is a map of the instrument's dust population	halo shape invariant after a controlled contamination event	null-testable
B013	atmosphere	The radiosonde's pump lag is a ventilation measurement, not an error	lag time independent of ascent rate over a 3× range	null-testable, quantitative, sweepable
B017	plant-agriculture	The porometer's leaf clamp is an embolism detector	recovery time constant independent of the measured xylem pressure at the cavitation threshold	null-testable, sweepable

id	field	claim	kill test	tags
B019	immunology	Assay background is a complement-activity measurement	background independent of a complement-specific functional assay across donors	null-testable, existing-data
B021	ecology-evolution	Detector false positives are a biodiversity signal, not a contamination	false-positive composition invariant to site while true composition changes	null-testable
B027	energy-systems	Calendar self-discharge is a separator-pore-quality assay	self-discharge rate independent of measured pore-size tail across separators	null-testable, sweepable
B028	manufacturing	Machine-tool thermal drift is a spindle-preload meter	drift time constant invariant to a controlled preload change	null-testable

Operator 2 — Limit-taking: the extreme case everyone avoids

Limit-taking survives when the limit is reachable with existing apparatus and the model's failure is predicted before the measurement.

id	field	claim	kill test	tags
B032	soft-matter	At infinite dilution, colloidal diffusivity deviates from Stokes–Einstein because the solvent's own correlation length matters	D matching Stokes–Einstein within 2% for a 2 nm tracer across three solvents of different correlation length	quantitative
B036	ultrafast	At zero delay, the pump–probe signal contains a coherent artefact that measures the pulse's absolute phase	zero-delay signal invariant to a known phase step applied by a shaper	null-testable
B037	quantum-devices	At zero bias, a tunnel junction's current noise measures the electromagnetic environment's impedance	zero-bias noise invariant when a known series impedance is inserted	null-testable

id	field	claim	kill test	tags
B040	astrophysics	At zero metallicity, the initial mass function is measurably top-heavy, and the evidence is in the elemental abundance ratios of the oldest stars	alpha/Fe at [Fe/H] < -4 consistent with the solar-metallicity IMF prediction	quantitative
B041	planetary	At zero atmospheric pressure, a body's surface still has a measurable gas layer from regolith outgassing, and it controls the surface temperature	nightside temperature matching a pure-radiation model to within 1 K	quantitative, sweepable
B043	atmosphere	At zero wind shear, the boundary layer still generates turbulence from surface heterogeneity at a predictable scale	turbulence intensity independent of mosaic length at zero shear	null-testable, theorem-backed
B046	microbiology	At zero growth rate, bacteria maintain a measurable maintenance energy that sets the death rate	survival time independent of initial ATP at fixed species	null-testable
B048	neuroscience	At zero spikes, neurons still consume oxygen at a rate set by synaptic vesicle cycling	oxygen consumption independent of release-probability manipulations at zero firing	null-testable
B049	immunology	At zero antigen, naive T cells still proliferate at a rate set by self-peptide affinity	baseline division rate independent of self-peptide affinity in TCR transgenic lines	null-testable, sweepable
B057	energy-systems	At zero current, a battery still ages through a calendar pathway whose rate is set by the electrode's stored energy, not its voltage	calendar aging independent of state of charge at fixed voltage	null-testable

Operator 3 — Cross-domain transplant

Transplants survive when the borrowed mechanism makes a numerical prediction the host field has never tested, not merely a suggestive analogy.

id	field	claim	kill test	tags
B062	electrochemistry ← semiconductor physics	The electrode's double layer has a depletion-length analogue, and the capacitance minimum occurs at the point of zero charge in a way predicted by the Mott–Schottky relation	capacitance–voltage slope independent of doping across a decade	null-testable, existing-data
B063	catalysis ← enzymology	Supported catalysts show substrate inhibition, not just site blocking, and the inhibition constant is measurable from the rate maximum's position	rate maximum position independent of substrate concentration across catalysts	null-testable, sweepable
B064	photochemistry ← nuclear physics	Photon echoes in molecular aggregates show a "magic angle" revival analogous to spin echoes, and the revival time measures the inhomogeneous width directly	revival time independent of the disorder width	null-testable, existing-data, theorem-backed
B070	planetary ← tribology	Lunar dust levitation is a triboelectric charging problem with a measurable charge-to-mass threshold identical to industrial powder handling	lofting threshold independent of the measured work function difference	null-testable, existing-data
B071	geophysics ← materials science	Fault gouge has a grain-boundary sliding law, and the seismic coupling coefficient is the same parameter as the creep exponent	coupling coefficient independent of the measured n across faults	null-testable, theorem-backed
B074	hydrology-soil ← polymer physics	Soil aggregates have a reptation-like relaxation, and infiltration curves show the reptation time	infiltration time constant independent of binder molecular weight	null-testable
B077	neuroscience ← condensed matter	Cortical avalanches have a Griffiths phase, not a critical point, and the Griffiths	avalanche exponent independent of the perturbation strength	null-testable

id	field	claim	kill test	tags
		temperature is measurable from the avalanche rate's temperature dependence		
B080	ecology-evolution ← finance	Extinction cascades have the same tail exponent as financial drawdowns because both are driven by the same branching process	cascade tail exponent differing from 3/2 by more than 0.2 across independent food webs	quantitative
B084	materials-failure ← biology	Fatigue crack growth has a "healing" analogue in metals at high temperature, and the healing rate is set by the same diffusion that sets creep	threshold stress intensity independent of temperature at fixed diffusion coefficient	null-testable, existing-data, sweepable
B089	signal-information ← thermodynamics	Compressed sensing has a Landauer cost, and the cost is measurable as heat in the reconstruction hardware	heat output independent of the number of measurements	null-testable, quantitative

Operator 4 — Conservation accounting

Conservation tests survive when the books can be closed with an independent measurement; the rest are bookkeeping without a second number.

id	field	claim	kill test	tags
B092	soft-matter	The measured yield stress of a suspension exceeds the stress the particles can transmit, and the excess is the solvent's viscoelasticity	yield stress independent of solvent molecular weight at fixed particle loading	null-testable
B099	nuclear-particle	The missing energy in a detector is not neutrinos but a slow component with a measurable delay	missing energy independent of the integration gate width	null-testable
B102	geophysics	The seismic moment budget of a fault does not close, and the missing moment is aseismic slip	moment budget closing with only seismic events across faults of different transition depth	needs-new-apparatus

id	field	claim	kill test	tags
		with a specific depth signature		
B108	neuroscience	The brain's energy budget does not close, and the missing expenditure is in glial cycling rather than neuronal firing	budget closing when glial cycling is inhibited	needs-new-apparatus
B109	immunology	The cytokine budget of an infection does not close, and the missing cytokine is bound to a soluble receptor that the assay cannot detect	free and total measurements closing the balance	theorem-backed
B112	medicine-diagnostics	The dose–response budget does not close, and the missing drug is in a tissue compartment that the plasma assay cannot see	mass balance closing with tissue measurement	needs-new-apparatus
B114	food-science	The mass balance of a drying process does not close, and the missing water is bound water with a different activity	closure error independent of the glass transition	null-testable, theorem-backed
B118	manufacturing	The material balance of an additive process does not close, and the missing powder is vaporised in a size-dependent way	loss independent of the powder's size distribution	null-testable
B119	acoustics-vibration	The acoustic energy budget of a room does not close, and the missing energy is transmitted through the structure rather than the air	budget closing with airborne paths alone at low frequency	sweepable
B120	signal-information	The information budget of a measurement does not close, and the missing information is in the timing of the samples rather than their values	channel capacity unchanged when timing jitter is removed	needs-new-apparatus

Operator 5 — Dimensionless coincidence

Universal ratios survive only if the expected universality comes with a number; those without a predicted value are excluded here.

id	field	claim	kill test	tags
B121	condensed-matter	The ratio of thermal to electrical boundary resistance at a metal–insulator interface is a universal number	ratio varying by more than 20% across metal–insulator pairs	quantitative, theorem-backed
B123	electrochemistry	The ratio of double-layer capacitance to bulk permittivity is a universal length of 0.3 nm across electrolytes	the ratio varying by more than 30% across electrolytes	quantitative
B124	catalysis	The volcano's apex occurs at a universal binding energy of -0.87 eV per adsorbate bond, independent of the reactant	apex position varying by more than 0.2 eV across reaction families	quantitative
B125	photochemistry	The Stokes shift of a fluorophore is a universal fraction of its emission energy	fraction varying by more than 30% across solvents at fixed fluorophore	quantitative
B127	quantum-devices	The ratio of T_2 to T_1 in superconducting qubits has a universal upper bound of 2	a device with $T_2 > 2T_1$ without non-Markovian evidence	quantitative, theorem-backed
B128	precision-metrology	The ratio of the clock's servo bandwidth to its linewidth is universal at 1	an operating point with a ratio outside 0.5–2 that outperforms	quantitative
B129	nuclear-particle	The ratio of the detector's energy resolution to its photoelectron yield is universal	ratio varying across scintillators by more than 20%	quantitative
B130	astrophysics	The ratio of the accretion disc's inner radius to the black hole's gravitational radius is a universal 6 for all masses	a measured ratio systematically different from 6 in a well-determined system	quantitative

id	field	claim	kill test	tags
B131	planetary	The ratio of a planet's magnetic moment to its angular momentum is universal across bodies with active dynamos	ratio varying by more than an order of magnitude across Earth, Jupiter, and Mercury	needs-new-apparatus
B141	ecology-evolution	The ratio of extinction rate to origination rate at equilibrium is universal at 1 across clades	ratio systematically different from 1 in well-sampled clades	quantitative

Operator 6 — Protocol archaeology

Protocol archaeology survives when the protocol's recording is available and varies naturally across a published corpus.

id	field	claim	kill test	tags
B151	condensed-matter	The reported resistivity of a metal film is a record of its measurement current	resistivity independent of measuring current from 1 μA to 1 mA at fixed geometry	null-testable, quantitative, existing-data
B152	soft-matter	The reported plateau modulus of a gel depends on the preshear history of the loading protocol, not on the gel	plateau modulus independent of the loading rate across two decades	null-testable, existing-data, sweepable
B153	electrochemistry	The reported exchange current density of an electrode is a record of its polishing grit	exchange current density independent of grit after ECSA normalisation	null-testable, existing-data
B155	photochemistry	The reported fluorescence quantum yield is a record of the cuvette's path length	quantum yield independent of path length after inner-filter correction	null-testable, quantitative, existing-data
B156	ultrafast	The reported electron–phonon coupling constant is a record of the probe wavelength	coupling constant independent of probe wavelength across the transparent window	null-testable, existing-data
B158	precision-metrology	The reported clock stability is a record of the data-analysis window	stability independent of the analysis window across a factor of four	null-testable, existing-data

id	field	claim	kill test	tags
B174	food-science	The reported shelf life is a record of the storage trial's temperature steps	shelf life independent of step spacing at fixed total exposure	null-testable, existing-data
B175	materials-failure	The reported fatigue limit is a record of the staircase test's step size	limit independent of step size across a factor of two	null-testable, existing-data
B178	manufacturing	The reported surface finish is a record of the stylus's skid	roughness independent of skid length across a factor of three	null-testable, existing-data
B179	acoustics-vibration	The reported sound power level is a record of the reverberation room's diffuseness	power level independent of room across two rooms of different volume	null-testable, existing-data

Operator 7 — Negative-result resuscitation

Resuscitated nulls survive when the null's bound can be re-derived and compared with a later positive claim.

id	field	claim	kill test	tags
B181	condensed-matter	The null result on "no field-induced resistivity change" is a bound on the electron's electric dipole moment in a solid	a re-derived limit weaker than the existing beam limit	theorem-backed
B182	soft-matter	The null result on "no shear thickening at low concentration" is a measurement of the solvent's excluded volume	onset concentration independent of the measured radius	null-testable, sweepable
B183	electrochemistry	The null result on "no oxygen evolution on the cathode" is a quantitative measurement of crossover	the bound weaker than the existing crossover measurement	theorem-backed
B184	catalysis	The null result on "no activity without the promoter" is a measurement of the background rate's origin	residual activity scaling with catalyst mass rather than wall area	needs-new-apparatus

id	field	claim	kill test	tags
B185	photochemistry	The null result on “no singlet oxygen in the absence of sensitiser” is a measurement of the solvent’s triplet yield	the bound weaker than a direct measurement of the solvent’s yield	theorem-backed
B186	ultrafast	The null result on “no coherent phonon above 100 K” is a measurement of the electron–phonon coupling’s temperature dependence	the bound weaker than a later positive measurement	theorem-backed
B188	precision-metrology	The null result on “no Lorentz violation” is a measurement of the apparatus’s orientation stability	the bound independent of the platform’s measured tilt noise	null-testable
B191	planetary	The null result on “no methane on Mars” is a measurement of the surface’s adsorption capacity	adsorption capacity measured to be far larger than the bound requires	needs-new-apparatus
B192	geophysics	The null result on “no precursory signal before earthquakes” is a measurement of the strain sensitivity of the network	the bound weaker than the network’s measured strain noise	needs-new-apparatus
B204	food-science	The null result on “no pathogen growth at this pH” is a measurement of the undissociated acid fraction	growth in a pH-matched control with a different acid	needs-new-apparatus

Operator 8 — Scale collision

Scale collisions survive when both scales are independently measurable, so the crossover can be located rather than assumed.

id	field	claim	kill test	tags
B216	ultrafast	The electron–phonon equilibration time and the pulse duration are comparable, so the measured temperature is a function of the pulse's chirp	extracted temperature independent of chirp at fixed fluence	null-testable, sweepable
B217	quantum-devices	The qubit's anharmonicity and its linewidth are comparable in a transmon near the sweet spot, so the leakage channel opens and mimics a coherence limit	leakage rate independent of anharmonicity across a tunable-transmon series	null-testable, sweepable
B221	planetary	The diurnal thermal skin depth and the regolith's grain size are comparable on small bodies, so the thermal inertia's interpretation changes	thermal inertia independent of grain size	null-testable
B225	hydrology-soil	The rainfall's correlation length and the hillslope's length are comparable, so the runoff coefficient becomes scale-dependent	runoff coefficient independent of storm correlation length	null-testable
B226	microbiology	The colony's height and the oxygen penetration depth are comparable, so the growth rate is set by the colony's aspect ratio	growth rate independent of colony aspect ratio	null-testable, existing-data, sweepable
B228	neuroscience	The synaptic cleft and the glutamate diffusion length are comparable, so transmitter spillover is set by the synapse's geometry rather than its release probability	spillover independent of cleft width	null-testable
B233	pharmacology	The drug's diffusion depth and the biofilm's thickness are comparable, so	MIC independent of biofilm thickness	null-testable, sweepable

id	field	claim	kill test	tags
		the MIC depends on biofilm geometry rather than on the drug		
B234	food-science	The ice crystal's size and the light's wavelength are comparable, so the food's appearance depends on the crystal distribution rather than the water content	appearance independent of crystal size at fixed water content	null-testable
B235	materials-failure	The crack-tip process zone and the grain size are comparable, so fracture toughness becomes a function of texture rather than of the grain boundary	toughness independent of texture at fixed grain size	null-testable, theorem-backed
B236	structural-civil	The soil's wavelength at the building's frequency and the foundation's width are comparable, so soil–structure interaction depends on the impedance contrast in a way that a Winkler model misses	interaction independent of foundation width at fixed soil	null-testable

Operator 9 — Symmetry and antisymmetry

Symmetry residuals survive when the symmetry-breaking term is independently measurable and the residual scales with it.

id	field	claim	kill test	tags
B241	condensed-matter	A centrosymmetric crystal shows a measurable photovoltaic current from its surface alone, and the surface's symmetry breaking is quantifiable	current vanishing as 1/thickness at fixed surface	quantitative, theorem-backed, sweepable
B242	soft-matter	An isotropic suspension shows a measurable normal-stress difference in steady shear,	normal-stress difference independent of gap	null-testable, theorem-backed

id	field	claim	kill test	tags
		which isotropy forbids		
B243	electrochemistry	A symmetric redox couple shows a measurable rectification, which the Butler–Volmer symmetry forbids	rectification vanishing on a dipole-free (hydrogen-terminated) surface	theorem-backed
B244	catalysis	An achiral catalyst produces a measurable enantiomeric excess, which symmetry forbids	excess independent of support handedness	null-testable, existing-data, theorem-backed
B248	precision-metrology	A clock's frequency shift reverses sign with the apparatus's orientation in a way that Lorentz invariance forbids	shift vanishing when the shield is made symmetric	theorem-backed
B250	astrophysics	A rotating galaxy's warped disc shows a measurable lopsidedness that the axisymmetric model forbids	lopsidedness independent of the halo's measured asymmetry	null-testable, quantitative, theorem-backed
B251	planetary	A planet's magnetic field has a measurable quadrupole that the dipole model forbids	quadrupole consistent with zero at the measured precision	theorem-backed
B253	atmosphere	A cyclone's outflow is asymmetric in a way that the gradient-wind balance forbids	asymmetry independent of translation speed	null-testable, theorem-backed
B254	ocean-ice	Sea ice's permeability is anisotropic in a way that the random-pore model forbids	isotropy in ice with a measured random texture	theorem-backed
B263	pharmacology	A drug's tissue distribution is asymmetric between left and right in a way that systemic perfusion forbids	symmetry after intravenous dosing that bypasses the lung	theorem-backed

Operator 10 — Sign reversal

Sign reversals survive when the competing mechanism has a predictable crossover condition rather than an arbitrary one.

id	field	claim	kill test	tags
B273	electrochemistry	The electrode's potential shifts positively on illumination in a material with the expected negative photovoltage	sign independent of surface treatment	null-testable
B274	catalysis	A promoter that should increase activity decreases it at high coverage	monotonic activity increase with promoter coverage	needs-new-apparatus
B276	ultrafast	The transient transmission increases where the excited-state absorption should decrease it	sign independent of probe detuning	null-testable
B277	quantum-devices	The qubit's frequency shifts up with applied gate voltage where the Stark effect requires a downshift	shift direction independent of gate geometry	null-testable
B278	precision-metrology	The clock's frequency shifts up with temperature where the cavity's expansion requires a downshift	sign independent of fibre length	null-testable
B279	nuclear-particle	The detector's pulse height increases with bias where the field should improve collection and increase height	monotonic height with bias at constant dark current	needs-new-apparatus
B283	atmosphere	The aerosol's radiative forcing is positive at a wavelength where scattering requires negative	forcing sign independent of size	null-testable
B285	hydrology-soil	The infiltration rate decreases with initial moisture over a range where it should increase	monotonic increase in a non-swelling soil	needs-new-apparatus
B287	plant-agriculture	The photosynthetic rate decreases with CO_2 over a range where it should increase	monotonic increase in a fertilised soil	needs-new-apparatus
B288	neuroscience	The synaptic response decreases with	monotonic increase at low stimulation rates	sweepable

id	field	claim	kill test	tags
		release probability over a range where it should increase		

Operator 11 — Threshold law

Threshold laws survive when the threshold value is predicted in advance by a dimensionless group; otherwise they are curve-fitting.

id	field	claim	kill test	tags
B301	condensed-matter	A metal film's resistivity has a sharp kink at the thickness where the surface scattering length equals the grain size	smooth resistivity–thickness curve through the predicted crossover	sweepable
B302	soft-matter	A colloidal gel has a sharp liquid–solid transition at a fixed number of bonds per particle, independent of chemistry	transition at coordination values varying by more than 0.3 across chemistries	quantitative
B303	electrochemistry	Dendrite nucleation has a sharp threshold in the ratio of current density to the diffusion-limited current, at 0.8	nucleation at ratios varying by more than 20% across electrolytes	quantitative, existing-data
B304	catalysis	Catalyst deactivation has a sharp onset at a coke loading that corresponds to one monolayer on the active phase	deactivation gradual through the monolayer point	needs-new-apparatus
B305	photochemistry	Singlet fission has a sharp threshold in the excitation density where biexciton annihilation overtakes fission	quantum yield smooth through the predicted density	existing-data
B306	ultrafast	Above a fluence threshold, the transient reflectivity's sign flips because the electron gas becomes degenerate	no sign flip up to the damage threshold	needs-new-apparatus
B308	precision-metrology	Above a critical atom number, the clock's stability stops improving	stability improving as √N beyond the predicted number	needs-new-apparatus

id	field	claim	kill test	tags
		because of cavity pulling		
B309	nuclear-particle	Above a critical event rate, the detector's dead time becomes nonlinear and the measured rate saturates at a calculable value	measured rate exceeding the paralysable maximum	quantitative, sweepable
B312	geophysics	Above a critical slip rate, friction drops sharply (the flash-weakening threshold)	smooth friction–velocity curve through the predicted rate	sweepable
B314	ocean-ice	Above a critical brine volume, sea ice becomes permeable in a sharp step at 5%	permeability smooth through 5%	quantitative

Operator 12 — Memory and hysteresis

Memory effects survive when the memory time is long compared with the protocol and short compared with the storage time.

id	field	claim	kill test	tags
B333	electrochemistry	An electrode remembers its last potential for minutes, and the memory sets the apparent exchange current	exchange current independent of the prior potential's hold time	null-testable, existing-data
B334	catalysis	A catalyst remembers the reactant's partial pressure for hours, and the memory sets the apparent order	order independent of the pre-treatment pressure	null-testable, sweepable
B335	photochemistry	A fluorophore remembers its excitation intensity for seconds, and the memory sets the measured lifetime	lifetime independent of the prior excitation	null-testable
B342	geophysics	A fault remembers its last large earthquake for centuries, and the memory sets the next event's size	event sizes independent of the previous event's extent	null-testable
B343	atmosphere	The atmosphere remembers a volcanic eruption for years, and the memory sets the aerosol's size distribution	size distribution independent of the eruption's age	null-testable

id	field	claim	kill test	tags
B345	hydrology-soil	A soil remembers its wetting history for weeks, and the memory sets its contact angle	contact angle independent of the wetting history	null-testable
B348	neuroscience	A synapse remembers a stimulation pattern for hours, and the memory sets its release probability	release probability independent of the prior pattern	null-testable
B357	energy-systems	A cell remembers a fast charge, and the memory sets its subsequent plating risk	plating risk independent of the prior fast charge	null-testable, existing-data
B358	manufacturing	A tool remembers a hard spot, and the memory sets its wear rate	wear rate independent of the prior hard spot	null-testable, sweepable
B360	signal-information	A channel remembers a burst of errors, and the memory sets the next burst's probability	burst probability independent of the prior burst	null-testable

Operator 13 — Crowding and interference

Interference effects survive when the coupling can be switched off, which is the only clean control.

id	field	claim	kill test	tags
B361	condensed-matter	Two adjacent thermocouples on a chip interfere through the substrate's thermal spreading, and the interference sets the apparent ZT	ZT independent of junction spacing	null-testable, existing-data
B366	ultrafast	Two pump beams interfere through the sample's accumulated heat, and the interference sets the measured relaxation	relaxation independent of the pump's spatial pattern	null-testable
B371	planetary	Two craters interfere through the ejecta's blanketing, and the interference sets the age	age independent of the neighbour's proximity	null-testable

id	field	claim	kill test	tags
B372	geophysics	Two faults interfere through the shared stress field, and the interference sets the recurrence	recurrence independent of the neighbour's events	null-testable
B375	hydrology-soil	Two rain gauges interfere through the shared wind field, and the interference sets the undercatch	undercatch independent of the upstream gauge	null-testable
B376	microbiology	Two colonies interfere through the shared nutrient, and the interference sets the growth rate	growth rate independent of neighbour distance	null-testable, sweepable
B378	neuroscience	Two electrodes interfere through the shared reference, and the interference sets the local field's amplitude	amplitude independent of the reference's position	null-testable
B380	developmental-biology	Two adjacent cells interfere through the shared morphogen, and the interference sets the fate boundary	boundary independent of the neighbour's fate	null-testable, theorem-backed
B382	medicine-diagnostics	Two analytes interfere through the shared antibody, and the interference sets the false positive	false positive independent of the cross-reactant's concentration	null-testable, sweepable
B387	energy-systems	Two cells in a pack interfere through the shared thermal path, and the interference sets the aging rate	aging rate independent of the neighbour's load	null-testable, sweepable

Operator 14 — Selection inversion

Selection inversions survive when the selection variable is recorded and its distribution can be reweighted.

id	field	claim	kill test	tags
B391	condensed-matter	Reported superconductors are selected for being easy to make, and the selection biases the apparent Tc–structure relation	the relation unchanged in a pressure-synthesised sample	sweepable

id	field	claim	kill test	tags
B393	electrochemistry	Reported catalyst stability is selected for surviving the first hour, and the selection hides the fast-failing majority	stability distribution including failures matching the reported one	needs-new-apparatus
B394	catalysis	Reported turnover frequencies are selected for catalysts that were characterised successfully, and the selection biases toward high surface area	TOF distribution including uncharacterised samples	existing-data
B395	photochemistry	Reported quantum yields are selected for emitters bright enough to measure, and the selection truncates the low-yield tail	yield distribution measured with a brighter detection scheme	needs-new-apparatus
B396	ultrafast	Reported relaxation times are selected for samples that survived the laser, and the selection biases toward robust materials	relaxation distribution including damaged samples	existing-data
B397	quantum-devices	Reported coherence times are selected for qubits that were measurable, and the selection biases toward the sweet spot	coherence distribution including untunable devices	needs-new-apparatus
B398	precision-metrology	Reported clock comparisons are selected for agreement, and the selection hides the discrepant runs	distribution including rejected runs matching the accepted one	needs-new-apparatus
B399	nuclear-particle	Reported cross sections are selected for detectable final states, and the selection biases the branching ratios	branching ratios including undetected modes	needs-new-apparatus
B400	astrophysics	Reported exoplanet radii are selected for transiting	radius distribution corrected for geometry	needs-new-apparatus

id	field	claim	kill test	tags
		geometry, and the selection biases the radius distribution at small sizes	matching the reported one	
B403	atmosphere	Reported extreme rainfall is selected for gauge density, and the selection biases the trend	trend corrected for density matching the reported one	needs-new-apparatus

Operator 15 — Units and definition traps

Unit traps survive when both conventions are in use and the conversion factor is measurable rather than conventional.

id	field	claim	kill test	tags
B421	condensed-matter	The reported carrier mobility depends on whether the sheet density is quoted per square or per unit volume, and the conversion hides a factor of the film's thickness	mobility independent of the measured thickness across a thickness series	null-testable, sweepable
B426	ultrafast	The reported pulse energy depends on whether it is quoted before or after the compressor's loss	energy independent of the measurement point	null-testable
B430	astrophysics	The reported luminosity depends on the assumed cosmology	luminosity independent of the assumed cosmology at low redshift	null-testable, existing-data
B431	planetary	The reported crater age depends on the assumed production function	age independent of the production function's choice	null-testable
B433	atmosphere	The reported aerosol optical depth depends on the assumed angstrom exponent	the depth independent of the assumed exponent	null-testable
B434	ocean-ice	The reported ice concentration depends on the tie point's assumed emissivity	concentration independent of the tie point	null-testable, sweepable
B437	plant-agriculture	The reported yield depends on the moisture	yield independent of the reference at fixed moisture	null-testable

id	field	claim	kill test	tags
		content's reference		
B440	developmental-biology	The reported stage depends on the reference's temperature	stage independent of the rearing temperature	null-testable, sweepable
B445	materials-failure	The reported hardness depends on the indenter's geometry and the load	hardness independent of load above the size-effect regime	null-testable
B446	structural-civil	The reported strength depends on the specimen's shape factor	strength independent of the shape factor after conversion	null-testable

Operator 16 — Coincidence of time constants

Time-constant coincidences survive when a third parameter can move one constant without the other.

id	field	claim	kill test	tags
B451	condensed-matter	The electron–phonon relaxation time and the thermal diffusion time across a film coincide at a specific thickness, and every measurement in that window misattributes one to the other	relaxation time independent of thickness at the crossing	null-testable, sweepable
B453	electrochemistry	The double-layer charging time and the faradaic time constant coincide at a specific electrode size, and impedance misassigns the arc	arc assignment independent of electrode size	null-testable
B454	catalysis	The surface reaction's turnover time and the pore diffusion time coincide at a specific pellet size, and the apparent kinetics are neither	kinetics independent of pellet size at the crossing	null-testable
B456	ultrafast	The carrier–carrier scattering time and the probe's temporal resolution coincide at a specific fluence, and the measured rise is the instrument	rise time independent of fluence at the crossing	null-testable

id	field	claim	kill test	tags
B461	planetary	The surface's thermal inertia time and the diurnal period coincide at a specific latitude, and the retrieved property is degenerate	retrieval independent of latitude at the crossing	null-testable
B465	hydrology-soil	The infiltration time and the evaporation time coincide at a specific soil texture, and the water balance is misattributed	balance independent of the texture at the crossing	null-testable
B466	microbiology	The doubling time and the dilution time in a chemostat coincide at a specific rate, and the steady state is misidentified	steady state independent of the dilution rate	null-testable, sweepable
B467	plant-agriculture	The stomatal opening time and the humidity's response time coincide, and the conductance measurement is the sensor's	conductance independent of the sensor's response time	null-testable
B474	food-science	The crystallisation time and the cooling time coincide at a specific rate, and the crystal size is set by the process rather than the formulation	size independent of the cooling rate	null-testable, sweepable
B476	structural-civil	The structure's period and the ground motion's period coincide, and the response is resonant rather than representative	response independent of the structure's period	null-testable

Operator 17 — Geometric frustration

Frustration effects survive when the constraint is geometric and the compromise point is computable.

id	field	claim	kill test	tags
B482	soft-matter	A confined colloidal crystal cannot close its lattice, so its melting temperature is	melting point independent of pore diameter	null-testable

id	field	claim	kill test	tags
		depressed in a way set by the pore's commensurability		
B483	electrochemistry	An intercalation electrode cannot satisfy both charge neutrality and lattice matching, so its voltage plateau is a frustration plateau	plateau potential independent of the particle size	null-testable, existing-data
B485	photochemistry	A chromophore in a rigid matrix cannot relax its excited state, so its emission is a frustration spectrum with a characteristic shape	spectrum independent of the matrix's stiffness	null-testable
B487	quantum-devices	A qubit coupled to two resonators cannot satisfy both matching conditions, so its Purcell protection is compromised at a computable detuning	protection independent of the second resonator's detuning	null-testable
B488	precision-metrology	A clock's interrogation cannot satisfy both the Ramsey and the Rabi conditions, so its lineshape is a frustration shape with a shifted centre	centre independent of the pulse area	null-testable
B492	geophysics	A fault cannot satisfy both the loading rate and the healing rate, and the resulting recurrence is a frustration period	recurrence independent of the healing rate	null-testable, sweepable
B493	atmosphere	A cloud cannot satisfy both the updraft's supply and the entrainment's dilution, and its droplet spectrum is a frustration spectrum	spectrum independent of the entrainment rate	null-testable, sweepable
B494	ocean-ice	Sea ice cannot satisfy both the salinity and the volume constraints, and the resulting brine network is a	network independent of the growth rate	null-testable, sweepable

id	field	claim	kill test	tags
		frustration pattern		
B495	hydrology-soil	A soil cannot satisfy both the infiltration and the drainage constraints, and the resulting moisture profile is a frustration profile	profile independent of the layer's thickness	null-testable, sweepable
B496	microbiology	A cell cannot satisfy both the growth and the division constraints, and the resulting size is a frustration size	size independent of the growth rate	null-testable, sweepable

Operator 18 — Noise as resource

Noise-as-resource survives when the fluctuation's spectrum is measurable at the required bandwidth.

id	field	claim	kill test	tags
B511	condensed-matter	The current noise of a disordered conductor measures its mesoscopic geometry, not just its resistance	Fano factor independent of the measured channel count	null-testable
B513	electrochemistry	The electrochemical noise measures the corrosion's localisation, not just its rate	noise power independent of the measured pit density	null-testable
B514	catalysis	The rate fluctuation measures the number of active sites, not just the turnover	variance independent of the measured site count	null-testable
B518	precision-metrology	The clock's Dick effect measures the local oscillator's noise at the interrogation frequency	effect independent of the oscillator's measured noise	null-testable
B521	planetary	The thermal infrared's fluctuation measures the regolith's grain size	spectrum independent of the measured grain size	null-testable
B524	ocean-ice	The ice's acoustic emission measures its deformation rate	emission rate independent of the measured strain	null-testable, sweepable

id	field	claim	kill test	tags
B526	microbiology	The gene expression's noise measures the promoter's state, not its mean	Fano factor independent of the measured promoter state	null-testable
B528	neuroscience	The membrane potential's noise measures the synapse count	variance independent of the measured synapse count	null-testable
B531	ecology-evolution	The population's fluctuation measures its resilience	return time independent of the measured fluctuation	null-testable
B535	materials-failure	The acoustic emission's fluctuation measures the crack's growth rate	emission rate independent of the measured growth rate	null-testable, sweepable

Operator 19 — The dead channel

Dead channels survive when the channel exists, is logged, and has never been calibrated.

id	field	claim	kill test	tags
B542	soft-matter	The rheometer's normal-force channel measures the sample's compressibility	force independent of the measured modulus	null-testable
B543	electrochemistry	The potentiostat's unused auxiliary channel measures the electrolyte's resistance	channel voltage independent of the measured resistance	null-testable
B544	catalysis	The reactor's unused pressure-drop channel measures the bed's compaction	drop independent of the measured compaction	null-testable
B545	photochemistry	The spectrophotometer's reference channel measures the lamp's aging	reference drift independent of the measured lamp output	null-testable
B546	ultrafast	The oscillator's unused error channel measures the laser's timing jitter	error signal independent of the measured jitter	null-testable
B547	quantum-devices	The cryostat's unused flux-line channel measures the magnetic field's noise	current independent of the measured field noise	null-testable, sweepable

id	field	claim	kill test	tags
B548	precision-metrology	The clock's unused correction channel measures the laboratory's pressure	correction independent of the measured pressure	null-testable, sweepable
B549	nuclear-particle	The detector's unused timing channel measures the interaction depth	timing independent of the measured depth	null-testable
B550	astrophysics	The telescope's unused guider channel measures the atmospheric seeing	motion independent of the measured seeing	null-testable
B561	ecology-evolution	The acoustic recorder's unused ultrasonic channel measures the insect community	ultrasonic power independent of the measured insect abundance	null-testable, existing-data

Operator 20 — Archive resurrection

Archive resurrections survive when the archive's metadata is rich enough to reconstruct the conditions.

id	field	claim	kill test	tags
B571	condensed-matter	1970s resistivity data on annealed metals contains the vacancy formation energy, recoverable because the annealing schedules were recorded	recovery stages not reproducible from the recorded schedules	existing-data
B572	soft-matter	Archived rheology on industrial polymers answers the tube-model question because their molecular weights were measured by an obsolete method that was more accurate	the old and new molecular weights disagreeing systematically	existing-data
B573	electrochemistry	Retired battery cycling data contains the SEI's growth law, recoverable from the capacity-fade curvature	fade curvature inconsistent with any SEI growth law	existing-data
B574	catalysis	Old pilot-plant data contains the catalyst's deactivation order, recoverable because the feed	decay shape independent of the logged poison	null-testable, existing-data

id	field	claim	kill test	tags
		composition was logged		
B577	quantum-devices	Early Josephson-junction data contains the quasiparticle density, recoverable from the subgap current	subgap current inconsistent with a thermal population	needs-new-apparatus
B579	nuclear-particle	Old bubble-chamber photographs contain the neutron's charge radius, recoverable from the track's multiple scattering	variance inconsistent with the known radiation length	existing-data
B580	astrophysics	Photographic plate archives contain the light echoes of historical transients, recoverable from the plate's grain noise	no echo recoverable from a plate with a known transient	existing-data
B581	planetary	Early spacecraft magnetometer data contains the solar wind's density, recoverable because the spacecraft's attitude was logged	the recovered density inconsistent with the contemporaneous monitor	existing-data
B583	atmosphere	Early radiosonde data contains the instrument's radiation bias, recoverable because the launch times are logged	bias independent of the logged launch time	null-testable, existing-data
B597	energy-systems	Old cell-testing data contains the lithium plating onset, recoverable from the voltage's relaxation	relaxation identical for cells with and without plating	existing-data

Operator 21 — Reverse engineering the pathology

Reverse-engineering survives when the failure mode is reproducible and the property is not otherwise accessible.

id	field	claim	kill test	tags
B601	condensed-matter	Delaminating a film measures its	buckle wavelength	null-testable

id	field	claim	kill test	tags
		interface toughness, a quantity no intact-sample test reaches	independent of the measured interface energy	
B602	soft-matter	Crushing a gel measures its strand persistence length	collapse pressure independent of the measured stiffness	null-testable, sweepable
B603	electrochemistry	Shorting a cell measures the separator's pore-size tail	onset current independent of the measured pore tail	null-testable
B604	catalysis	Poisoning a catalyst measures its site distribution	activity loss independent of the poison's uptake	null-testable
B605	photochemistry	Photobleaching a dye measures its triplet lifetime	bleach rate independent of the measured triplet lifetime	null-testable, sweepable
B606	ultrafast	Damaging a mirror measures its coating's absorption	threshold independent of the measured absorption	null-testable, existing-data
B607	quantum-devices	Overdriving a qubit measures its junction's critical current	switching independent of the measured critical current	null-testable
B608	precision-metrology	Unlocking a clock measures its cavity's drift	walk independent of the measured cavity drift	null-testable
B609	nuclear-particle	Overbiasing a detector measures its depletion voltage	onset independent of the measured depletion	null-testable
B624	food-science	Freeze-thawing a product measures its ice's recrystallisation	drip loss independent of the cycle count	null-testable

Operator 22 — Adversarial condition

Adversarial conditions survive when the failure is reversible, so the baseline can be recovered.

id	field	claim	kill test	tags
B632	soft-matter	Shearing a gel past its yield measures its structural recovery time	recovery independent of the shear's magnitude	null-testable
B633	electrochemistry	Cycling a cell at high rate measures its electrode's tortuosity	capability independent of the measured tortuosity	null-testable
B634	catalysis	Starving a reactor of reactant measures the	decay independent of	null-testable

id	field	claim	kill test	tags
		catalyst's oxygen storage	the measured storage	
B635	photochemistry	Quenching a reaction with a radical trap measures the radical's lifetime	suppression independent of the trap's concentration	null-testable, sweepable
B636	ultrafast	Chirping a pulse to its transform limit measures the medium's dispersion	required chirp independent of the measured dispersion	null-testable
B638	precision-metrology	Modulating a clock's frequency measures its servo's gain	amplitude independent of the measured gain	null-testable
B639	nuclear-particle	Overloading a detector measures its pile-up rejection	distortion independent of the measured rejection	null-testable
B640	astrophysics	Defocusing a telescope measures its pixel response	structure independent of the measured footprint	null-testable
B641	planetary	Overexposing an imager measures its charge diffusion	extent independent of the measured length	null-testable
B643	atmosphere	Saturating a hygrometer measures its response time	recovery independent of the measured constant	null-testable

Operator 23 — Extreme environment

Extreme environments survive only where the apparatus already reaches them; the rest are proposals.

id	field	claim	kill test	tags
B661	condensed-matter	At megabar pressure, the phonon's contribution to thermal conductivity saturates because the lattice becomes stiff enough that anharmonicity dominates	conductivity monotonic in pressure across the predicted point	sweepable
B662	soft-matter	At cryogenic temperatures, a glassy polymer's yield stress becomes temperature-independent because tunnelling dominates	yield stress continuing to fall to zero temperature	sweepable

id	field	claim	kill test	tags
B664	catalysis	At supercritical conditions, the catalyst's activity becomes independent of the support because the solvent's density homogenises the local environment	activity still support-dependent above the critical density	needs-new-apparatus
B666	ultrafast	At relativistic intensity, the plasma mirror's reflectivity becomes independent of the target material	reflectivity still material-dependent at the predicted intensity	needs-new-apparatus
B667	quantum-devices	At millikelvin temperatures, the qubit's dephasing becomes temperature-independent because the noise is dominated by a single two-level system	dephasing continuing to fall below the predicted temperature	sweepable
B670	astrophysics	At very high redshift, the metallicity floor becomes independent of the galaxy's mass because the intergalactic medium's enrichment dominates	floor still mass-dependent at the highest redshift	needs-new-apparatus
B671	planetary	At very high surface temperature, the rock's thermal conductivity becomes independent of composition because radiation dominates	conductivity still composition-dependent at the predicted temperature	sweepable
B672	geophysics	At very high strain rate, the fault's friction becomes rate-independent because the asperities melt	rate dependence persisting at the highest rates	sweepable
B676	microbiology	At very high pressure, the growth rate becomes independent of the temperature because the pressure	growth still temperature-dependent at the highest pressure	sweepable

id	field	claim	kill test	tags
		denatures the proteins		
B690	signal-information	At very high SNR, the capacity becomes independent of the coding scheme because the shaping gain saturates	a scheme gaining more than the shaping bound above the predicted SNR	theorem-backed

Operator 24 — Minimal system

Minimal systems survive when the simplification removes a mechanism rather than the effect itself.

id	field	claim	kill test	tags
B691	condensed-matter	A single-crystal, single-domain, strain-free sample shows no Kondo-like resistivity minimum	a minimum persisting in a sample with measured disorder below the detection limit	needs-new-apparatus
B695	photochemistry	A single molecule shows the same quantum yield as an ensemble	single-molecule yields differing by more than the ensemble's spread	needs-new-apparatus
B697	quantum-devices	A single-junction qubit shows the same coherence as a multi-junction one	coherence differing by more than the junction count's expected contribution	needs-new-apparatus
B703	atmosphere	A single-cloud system shows the same albedo susceptibility as a field of clouds	field susceptibility differing by more than the overlap's contribution	sweepable
B704	ocean-ice	A single brine channel shows the same permeability as the network	network permeability differing by more than the percolation factor	needs-new-apparatus
B705	hydrology-soil	A single-pore model shows the same retention curve as the soil	the curve not reproducible from the measured pore distribution	needs-new-apparatus
B706	microbiology	A single cell shows the same growth rate as the population	single-cell rates differing by more than the population's spread	sweepable
B707	plant-agriculture	A single leaf shows the same water-use efficiency as the canopy	canopy efficiency differing by more than the boundary-layer correction	needs-new-apparatus
B708	neuroscience	A single synapse shows the same plasticity rule as the network	network plasticity differing by more than the	needs-new-apparatus

id	field	claim	kill test	tags
			connectivity's contribution	
B714	food-science	A single-component model food shows the same texture as the real product	texture differing by more than the minor components' contribution	needs-new-apparatus

Operator 25 — Contradiction mining

Contradiction mining survives when both papers report the metadata needed to test the reconciling variable.

id	field	claim	kill test	tags
B721	condensed-matter	Two measurements of the same material's thermal conductivity differ by 3×, and both are right because they measure different tensor components with the same label	anisotropy measured and found insufficient to explain the discrepancy	needs-new-apparatus
B722	soft-matter	Two measurements of the same polymer's viscosity differ by an order of magnitude, and both are right because one is at a different solvent quality	solvent quality matched and the discrepancy persisting	needs-new-apparatus
B730	astrophysics	Two measurements of the same galaxy's mass differ, and both are right because one is dynamical and one is lensing, and they measure different mass components	the two agreeing after baryon correction	needs-new-apparatus
B732	geophysics	Two measurements of the same fault's slip rate differ, and both are right because one averages over the seismic cycle	the two agreeing at all timescales	existing-data
B733	atmosphere	Two measurements of the same aerosol's forcing differ, and both are right because one is at the top and one at the surface	the two agreeing after column correction	needs-new-apparatus

id	field	claim	kill test	tags
B734	ocean-ice	Two measurements of the same ice's thickness differ, and both are right because one includes the snow	the two agreeing after snow correction	needs-new-apparatus
B736	microbiology	Two measurements of the same strain's growth rate differ, and both are right because one is at a different oxygen tension	the two agreeing at matched oxygen	needs-new-apparatus
B739	immunology	Two measurements of the same antibody's affinity differ, and both are right because one is in solution and one on a surface	the two agreeing with a monovalent surface	needs-new-apparatus
B742	medicine-diagnostics	Two measurements of the same test's sensitivity differ, and both are right because one uses a different reference standard	the two agreeing with a perfect reference	needs-new-apparatus
B750	signal-information	Two measurements of the same channel's capacity differ, and both are right because one uses a different input distribution	the two agreeing at the optimal distribution	needs-new-apparatus

Operator 26 — Hidden conservation

Hidden conservation survives when the conserved quantity can be independently assayed.

id	field	claim	kill test	tags
B751	condensed-matter	The total momentum of the electron–phonon system is conserved, so the thermal and electrical resistivities must satisfy a relation tighter than Wiedemann–Franz in the phonon-drag regime	the relation violated in a clean metal at low temperature	theorem-backed, sweepable

id	field	claim	kill test	tags
B753	electrochemistry	The total ionic charge is conserved, so the cell's capacity and its impedance must satisfy a sum rule	the rule violated across a chemistry series	theorem-backed
B754	catalysis	The total number of active sites is conserved, so the TOF and the site density cannot both be varied freely	TOF and site density varying independently with independent measurements	theorem-backed
B755	photochemistry	The total photon number is conserved, so the quantum yield and the absorption cannot be independently optimised	a system exceeding the bound	theorem-backed
B760	astrophysics	The total baryon number is conserved, so the galaxy's stellar mass and its gas mass must sum to the cosmic value	the sum varying with the measurement method	theorem-backed
B762	geophysics	The total moment is conserved, so the seismic and aseismic slip must sum to the plate motion	the sum not matching the plate rate	existing-data, theorem-backed, sweepable
B763	atmosphere	The total water is conserved, so the precipitation and the evaporation must balance on the annual mean	a persistent imbalance at the global scale	theorem-backed
B765	hydrology-soil	The total water is conserved, so the storage and the flux must trade	the storage changing without a matching flux	theorem-backed
B767	plant-agriculture	The total carbon is conserved, so the biomass and the respiration must trade	the biomass increasing without a matching uptake	theorem-backed
B780	signal-information	The total probability is conserved, so the detection and false-alarm rates must trade	the two improved independently at the same threshold	theorem-backed

Operator 27 — Phase and coherence

Coherence anomalies survive only if the claimed coherence violates a measured decoherence channel.

id	field	claim	kill test	tags
B781	condensed-matter	A macroscopic mechanical oscillator retains coherence across a thermal cycle, which the fluctuation–dissipation theorem forbids	coherence lost as predicted from the measured Q	theorem-backed
B782	soft-matter	A colloidal crystal retains its registry across a shear cycle, which the melting criterion forbids	registry lost at strains below the predicted threshold	theorem-backed
B783	electrochemistry	An electrode's potential retains phase coherence with an applied oscillation across a redox cycle	coherence lost at the predicted cycle time	needs-new-apparatus
B784	catalysis	A catalyst's turnover retains a phase relation with a pulsed feed, which the steady-state assumption forbids	no phase relation at the pulse frequency	theorem-backed, sweepable
B786	ultrafast	A phonon mode retains coherence across an electronic excitation, which the anharmonic coupling forbids	coherence lost at the predicted coupling time	theorem-backed
B787	quantum-devices	Two distant qubits retain a phase relation through a shared resonator, which the Purcell effect forbids	the relation lost at the predicted detuning	theorem-backed
B788	precision-metrology	Two independent clocks retain a phase relation after their references are removed	the relation lost when the environments are isolated	needs-new-apparatus
B789	nuclear-particle	A detector's response retains phase coherence with a pulsed source across a long integration	the relation lost at the predicted integration time	needs-new-apparatus
B790	astrophysics	A pulsar retains phase coherence across a glitch, which the timing model forbids	coherence lost at the glitch	theorem-backed
B804	food-science	A fermentation retains phase	the trajectory independent of	null-testable

id	field	claim	kill test	tags
		coherence with the initial inoculum's state	the inoculum	

Operator 28 — Topological and global constraints

Topological constraints survive when the constraint is exact and the boundary condition is known.

id	field	claim	kill test	tags
B811	condensed-matter	A thin film's defects must sum to zero Burgers vector, so a single dislocation cannot exist and its absence is measurable	an isolated dislocation in a bounded film	needs-new-apparatus
B813	electrochemistry	The current's integral over a closed electrode surface must equal the total reaction rate, so a local measurement cannot exceed the global one	a local rate exceeding the global	theorem-backed, sweepable
B814	catalysis	The product's selectivity must sum to one across all products, so a reported selectivity above one is impossible	a reported selectivity above one not explained by an unmeasured product	needs-new-apparatus
B815	photochemistry	The quantum yield must satisfy a sum rule over all channels, so a yield above one requires a chain reaction	a yield above one without a chain mechanism	theorem-backed
B817	quantum-devices	The qubit's gate set must satisfy the unitarity constraint, so the reported fidelities cannot all be independently high	fidelities violating the constraint	needs-new-apparatus
B818	precision-metrology	The clock's error budget must satisfy the total variance, so the individual terms cannot all be at their limits	a budget whose terms sum above the measured variance	needs-new-apparatus
B819	nuclear-particle	The branching ratios must sum to one, so a reported set	a set above one without an unmeasured channel	theorem-backed

id	field	claim	kill test	tags
		above one is impossible		
B822	geophysics	The seismic moment tensor must satisfy the double-couple constraint for a shear event, so a non-double-couple component measures the source's complexity	a non-double-couple component in a simple event	needs-new-apparatus
B823	atmosphere	The wind field must satisfy the continuity equation, so a measured divergence bounds the vertical velocity	a divergence inconsistent with the vertical velocity	theorem-backed
B834	food-science	The product's composition must satisfy the mass balance, so the components sum to 100%	a composition above 100%	quantitative

Operator 29 — Statistical artefact with a physical signature

Artefact-with-signature survives when the artefact's period scales with an instrument parameter and the physics does not.

id	field	claim	kill test	tags
B841	condensed-matter	The apparent quantum oscillations in a magnetoresistance are a measurement artefact with a period set by the contact spacing, not the Fermi surface	the frequency invariant to contact geometry	null-testable, sweepable
B842	soft-matter	The apparent shear banding is an artefact of the velocity profile's inversion, with a band width set by the gap	the band width independent of the gap	null-testable
B845	photochemistry	The apparent blinking is an artefact of the detector's gain drift, with a timescale set by the electronics	the blinking invariant to the detector	null-testable

id	field	claim	kill test	tags
B847	quantum-devices	The apparent coherence revival is an artefact of the pulse generator's clock, with a period set by the clock's drift	the revival invariant to the generator	null-testable
B849	nuclear-particle	The apparent annual modulation is an artefact of the detector's calibration drift, with a period set by the maintenance schedule	the modulation invariant to the maintenance schedule	null-testable
B850	astrophysics	The apparent periodicity in the light curve is an artefact of the observing cadence, with a period set by the scheduling	the periodicity invariant to the cadence	null-testable
B852	geophysics	The apparent precursory signal is an artefact of the catalogue's reporting, with a pattern set by the network's operations	the signal invariant to the network's operations	null-testable, existing-data
B854	ocean-ice	The apparent thinning is an artefact of the sensor's drift, with a rate set by the buoy's power budget	the thinning invariant to the sensor's power	null-testable
B863	pharmacology	The apparent interaction is an artefact of the sampling time, with a pattern set by the schedule	the interaction invariant to the sampling schedule	null-testable
B867	energy-systems	The apparent aging is an artefact of the test's temperature, with a rate set by the chamber	the aging invariant to the chamber's temperature	null-testable, sweepable

Operator 30 — The exception that proves the rule

Exceptions survive when the anomaly's cause is measurable and the rest of the sample is a matched control.

id	field	claim	kill test	tags
B871	condensed-matter	One crystal in a batch shows	the anomaly absent when the	needs-new-apparatus

id	field	claim	kill test	tags
		anomalous superconductivity, and its anomaly measures the strain sensitivity of the transition	strain is matched	
B873	electrochemistry	One electrode in a series shows an anomalously low overpotential, and its anomaly measures the facet's activity	the anomaly absent when the facet is matched	needs-new-apparatus
B874	catalysis	One catalyst batch is anomalously active, and its anomaly measures the support's impurity	the anomaly absent when the impurity is matched	needs-new-apparatus
B875	photochemistry	One sample is anomalously bright, and its anomaly measures the aggregate's quantum yield	the anomaly absent when the aggregation is matched	needs-new-apparatus
B876	ultrafast	One run shows an anomalously long relaxation, and its anomaly measures the sample's oxidation	the anomaly absent when the oxidation is matched	needs-new-apparatus
B877	quantum-devices	One qubit is anomalously coherent, and its anomaly measures the substrate's loss tangent	the anomaly absent with a matched substrate	sweepable
B878	precision-metrology	One run shows an anomalously low drift, and its anomaly measures the cavity's thermal time constant	the anomaly absent at a matched environment	needs-new-apparatus
B879	nuclear-particle	One detector is anomalously quiet, and its anomaly measures the radon's rejection	the anomaly absent with a matched seal	needs-new-apparatus
B880	astrophysics	One galaxy is anomalously metal-poor, and its anomaly measures the inflow's dilution	the anomaly absent at a matched accretion rate	sweepable
B881	planetary	One crater is anomalously young, and its	the anomaly absent at a	needs-new-apparatus

id	field	claim	kill test	tags
		anomaly measures the resurfacing's rate	matched resurfacing	

Part III — The refined 30

Thirty of the 300 were taken further. Each entry states what survived screening, the mechanism in one line, the decisive test, and the refutation. Three (R10, R12, R23) are developed to proof grade in Part IV.

Status key. `proven` = a derivation plus a numerical check exists in this bundle. `conditional` = a derivation holds under stated assumptions. `open` = a test is specified but not performed.

R01 · B001 — Cryostat drift is a phonon-conductance meter

Claim. The slow thermal drift of a sample in a cryostat is not noise; it is a measurement of the sample's conductance to the bath. **Survived because.** The drift is already logged, the mounting conductance is the one parameter nobody measures in situ, and the kill test is a one-week sweep on existing hardware. **Mechanism.** A parasitic heat leak raises the sample above the bath at a rate set by the series conductance of the mounting; the drift's time constant is the sample's heat capacity divided by that conductance. Both are measurable from the same trace. **Decisive test.** Vary the mounting conductance (indium foil versus grease versus silver paint) at fixed leak; the drift time constant should scale linearly with the conductance while the asymptotic offset does not. **Refuted if.** The time constant is independent of mounting across a decade. **Status.** `open`. The idea is cheap but the leak term is usually unknown, which is the weak point.

R02 · B003 — Uncompensated resistance as a microkelvin thermometer

Claim. The electrolyte resistance between working and reference electrodes is a thermometer with ∼5 mK resolution at 10 Ω. **Survived because.** dR/dT of a 0.1 M electrolyte is ∼2%/K, the resistance is measured in every experiment, and the test needs no new instrument. **Mechanism.** The temperature coefficient of ionic conductivity, not any special sensor. **Decisive test.** Drive a known small temperature oscillation at the cell and compare the resistance-derived temperature with a thermocouple inside the electrolyte. **Refuted if.** The two disagree in phase or amplitude beyond the ionic-conductivity model. **Status.** `open`, but the effect is a known nuisance in precision electrochemistry. The new part is treating it as the measurement.

R03 · B008 — The servo error signal is a sub-nanometre displacement sensor

Claim. In a locked interferometer the error channel is a calibrated displacement readout whose gain is set by the feedback itself. **Survived because.** The channel exists in every locked experiment and is normally discarded; the calibration is self-referential rather than assumed. **Mechanism.** When the loop is locked, the error signal is the residual displacement times the discriminant slope, and the loop's own gain calibration fixes that slope. **Decisive test.** Compare the error-channel spectrum with an independent seismometer or a second interferometer in the same band. **Refuted if.** The two spectra differ by more than the loop's measured suppression. **Status.** `open`. The method is standard in some labs and absent in most, which is what makes it worth stating.

R04 · B022 — ECG baseline wander is a respiration monitor

Claim. The low-frequency wander of a single-lead ECG measures tidal volume better than a belt in ambulatory recordings. **Survived because.** Every ECG has the channel, the data are ubiquitous, and the comparison against spirometry is a secondary analysis. **Mechanism.** The wander is driven by thoracic impedance and

by electrode motion, both of which track the respiratory cycle. **Decisive test.** Simultaneous ECG and spirometry across posture changes; the wander-derived volume should track spirometry with a posture-dependent gain but a stable phase. **Refuted if.** The phase between wander and spirometry is unstable across subjects. **Status.** `open`. A known nuisance turned into a sensor; the gain's posture dependence is the likely failure mode.

R05 · B031 — Wiedemann–Franz must fail at the bottom of the temperature range

Claim. In a dirty metal below ~1 K the Lorenz ratio falls measurably below the Sommerfeld value because impurity scattering dominates the electrical channel while the thermal channel is limited by a different mechanism. **Survived because.** Every low-temperature thermal-conductivity paper reports both quantities; the deviation is a reanalysis, not a new measurement. **Mechanism.** The two conductivities are limited by different scattering integrals once electron–electron and electron–phonon terms freeze out. **Decisive test.** Reanalyse published pairs at fixed residual resistivity ratio; the Lorenz ratio should fall with decreasing temperature with a slope set by the impurity's scattering phase shift. **Refuted if.** The ratio stays within 5% of Sommerfeld down to 50 mK in samples spanning a decade in residual resistivity ratio. **Status.** `open`.

R06 · B033 — Transference numbers without supporting electrolyte

Claim. With no added salt, migration and diffusion decouple in time, so the transference number can be read from the early-time current transient. **Survived because.** The measurement is one step-response on an existing cell and removes a tracer-method calibration. **Mechanism.** In a binary electrolyte the cation and anion fluxes respond on different timescales once the concentrated-solution theory is retained; the short-time slope of the current is set by the transference number. **Decisive test.** Compare with a concentration-cell measurement on the same electrolyte. **Refuted if.** The two disagree by more than 10% across a concentration series. **Status.** `open`. The concentrated-solution theory needed is standard; the risk is that the transient is dominated by double-layer charging instead.

R07 · B037 — Zero-bias noise measures the electromagnetic environment

Claim. The current noise of a tunnel junction at zero bias measures the real part of the environment impedance at the junction's plasma frequency. **Survived because.** The measurement needs only a quiet amplifier, and the environment is otherwise invisible. **Mechanism.** The junction's shot noise is partly converted to voltage noise by the environment; the conversion is the impedance. **Decisive test.** Insert a known series impedance and check that the zero-bias noise changes by the predicted amount. **Refuted if.** The noise is unchanged when the impedance is varied by a factor of three. **Status.** `open`.

R08 · B091 — Heat-capacity addenda do not satisfy the sum rule they are assumed to

Claim. The measured heat capacity of a thin film violates the Dulong–Petit sum rule by an amount that equals the substrate's strain-induced contribution. **Survived because.** The sum rule is exact at high temperature, the addenda correction is universal, and the test needs two substrates rather than a new calorimeter. **Mechanism.** The film's misfit strain shifts the substrate's phonon spectrum in a thin surface layer; the standard addenda subtraction removes the bulk substrate only. **Decisive test.** Same film on substrates of two thicknesses; the residual after addenda subtraction should scale with the surface-to-volume ratio

of the substrate. **Refuted if.** The residual is substrate-thickness independent. **Status.** `open`. The expected magnitude is small; this is the weakest of the conservation set and is included because the test is cheap.

R09 · B121 — A universal Lorenz ratio at metal–insulator interfaces

Claim. The ratio of thermal to electrical boundary conductance is the same for every metal–insulator pair, because both are set by the same interfacial transmission. **Survived because.** Both quantities are measured in the same TDTR or 3ω experiment, and the prediction is a number rather than a trend. **Mechanism.** The Wiedemann–Franz relation applied to the interface: the ratio reduces to the Lorenz number times a geometric factor common to both channels. **Decisive test.** Compile pairs with independently measured electronic and thermal interface conductances; the ratio should be constant. **Refuted if.** The ratio varies by more than 20% across pairs. **Status.** `open`, and likely false: interface transmission for phonons and electrons is not the same function. Included because a clean refutation is valuable and cheap.

R10 · B127 — **PROOF**: $T_2 \le 2T_1$ is universal, and the ratio is a noise-spectrum meter

Claim. No pulse sequence can push T_2 above $2T_1$, because energy relaxation is not refocusable; and the ratio T_2/T_1 *from two standard measurements measures the noise spectral index.* ***Survived because.*** *It is a theorem with a corollary that turns two routine measurements into a spectrum estimate.* ***Mechanism.*** *Dephasing adds to $1/T_2$; it cannot subtract. Refocusing suppresses dephasing but leaves T_1 untouched, so every sequence saturates at the bound rather than crossing it.* ***Decisive test.*** *For a device with independently measured noise spectra, the FID ratio should follow the computed calibration $\beta \to T_2/T_1$.* **Refuted if.** A device with a measured 1/f spectrum returns a ratio inconsistent with the calibration at fixed band. **Status.** `proven` (Part IV). The original hypothesis — that refocusing escapes the bound — was **refuted by the calculation**; the bound is stronger than claimed and the ratio is more useful than the escape route.

R11 · B211 — Electron and phonon length scales collide in thermoelectrics

Claim. When the electron mean free path and the phonon wavelength are comparable, the Lorenz ratio drops and the maximum attainable zT is capped. **Survived because.** Both lengths are independently measurable, so the crossover can be located rather than assumed. **Mechanism.** Momentum exchange between the two systems redistributes the heat current. **Decisive test.** A mean-free-path series (alloying at fixed carrier density) with simultaneous thermal and electrical conductivity. **Refuted if.** zT follows the Wiedemann–Franz prediction through the crossover. **Status.** `open`.

R12 · B241 — **PROOF**: bulk and surface photocurrent are separable by a 1/d law

Claim. In a centrosymmetric film the bulk photovoltaic current vanishes by symmetry, so the measured current density must obey $J(d) = j_b + j_s/d$. **Survived because.** The scaling is exact, the two terms are separable by a thickness series, and the misassignment in the literature is large. **Mechanism.** A surface sheet current divided by thickness gives a 1/d term; the bulk term is the symmetry-forbidden remainder, which measures how badly the symmetry is broken. **Decisive test.** Thickness series from 20 nm to 2 μm; the two-parameter fit recovers j_b and j_s with the predicted uncertainties. **Refuted if.** J is thickness-independent in a centrosymmetric material with measured inversion symmetry. **Status.** `proven` (Part IV, conditional on the sheet-current model).

R13 · B303 — Dendrite nucleation at a fixed fraction of the limiting current

Claim. Plating nucleates when the current density reaches 0.8 of the diffusion-limited value, independent of electrolyte. **Survived because.** The ratio is dimensionless, the crossover is sweepable, and the prediction is a number. **Mechanism.** Above the threshold the depletion layer's instability growth rate exceeds the stabilising surface-tension term. **Decisive test.** Sand's-time measurements across three electrolytes at fixed separator. **Refuted if.** The onset ratio varies by more than 20% across electrolytes. **Status.** `open`. The 0.8 value is a guess with a plausible derivation; it is the kind of number that either lands or does not.

R14 · B391 — Reported superconductors are a selected sample

Claim. The apparent correlation between Tc and structure is partly a selection effect: the materials that form at ambient pressure are a non-random subset. **Survived because.** The selection variable is recorded, and a pressure-synthesised sample is a direct control. **Mechanism.** Synthesisability correlates with the same structural features that correlate with Tc. **Decisive test.** Compare the Tc–structure relation in ambient-pressure and high-pressure syntheses of the same family. **Refuted if.** The relation is unchanged in the pressure-synthesised set. **Status.** `open`.

R15 · B421 — Mobility is quoted in a unit that hides the thickness

Claim. Reported carrier mobility depends on whether sheet density is quoted per square or per volume, and the conversion hides a factor of the film thickness that is often assumed. **Survived because.** Both conventions are in active use and the thickness is usually estimated, not measured. **Mechanism.** The unit conversion is exact; the error enters through the assumed thickness. **Decisive test.** Recompute mobilities from papers that report both conventions plus a measured thickness. **Refuted if.** The two conventions agree within their stated uncertainties across a corpus. **Status.** `open`. A bookkeeping result, but the kind that changes rankings.

R16 · B451 — Coincident relaxation times in thin-film thermal metrology

Claim. At a specific film thickness the electron–phonon relaxation time equals the thermal diffusion time, and every measurement in that window misattributes one to the other. **Survived because.** Both timescales are independently calculable, so the crossing is predictable in advance. **Mechanism.** The two scale with thickness with different powers. **Decisive test.** TDTR across a thickness series spanning the predicted crossing. **Refuted if.** The extracted relaxation time is thickness-independent through the crossing. **Status.** `open`.

R17 · B481 — A film's transition temperature is a frustration temperature

Claim. On a rigid substrate the measured transition temperature is shifted by the biaxial strain that thermal expansion cannot relieve. **Survived because.** The Ehrenfest relation gives the shift quantitatively from measurable quantities. **Mechanism.** Clamping converts an isotropic expansion into a biaxial stress. **Decisive test.** The same film on substrates of different compliance. **Refuted if.** The transition temperature matches bulk on a rigid substrate. **Status.** `open`, though the effect is known in specific systems; the hypothesis is that it is large and unreported in general.

R18 · B511 — The Fano factor measures the number of conduction channels

Claim. Current-noise measurements recover the channel count of a disordered conductor, which resistance alone cannot. **Survived because.** The Fano factor's limits are exact (1/3 diffusive, 1 ballistic, 1/4 chaotic), so the test is a comparison against known values. **Mechanism.** Partition noise depends on the transmission eigenvalues, not just their sum. **Decisive test.** A disorder series with simultaneous noise and magnetoresistance. **Refuted if.** The Fano factor is independent of the measured channel count. **Status.** `open`, and established in mesoscopic physics; it is included because the measurement is rarely applied outside that field.

R19 · B601 — Delamination measures interface toughness

Claim. The buckle wavelength of a delaminated film gives the interface toughness, a quantity no intact-sample test reaches. **Survived because.** The buckle geometry is measurable by optical microscopy and the mechanics is closed-form. **Mechanism.** The buckle's wavelength is set by the balance of bending and interface energy. **Decisive test.** Delaminate films with controlled interface chemistry and compare with a four-point bend test. **Refuted if.** The wavelength is independent of the independently measured interface energy. **Status.** `open`, with established mechanics behind it.

R20 · B691 — The Kondo minimum is a disorder effect

Claim. A strain-free, single-domain sample shows no resistivity minimum, because the minimum requires disorder rather than the Kondo effect. **Survived because.** The test is a single high-quality sample and the prediction is a null. **Mechanism.** The minimum arises from the competition between impurity and phonon scattering with a distribution of Kondo temperatures; a clean sample has one Kondo temperature. **Decisive test.** Resistivity of a sample with measured disorder below the detection limit. **Refuted if.** The minimum persists in the cleanest sample. **Status.** `open`, and deliberately contrarian.

R21 · B721 — A 3× discrepancy that is not a discrepancy

Claim. Two measurements of the same material's thermal conductivity differ by 3× because they measure different tensor components under the same label. **Survived because.** The anisotropy is measurable and both papers are internally consistent. **Mechanism.** Unreported anisotropy plus an unstated measurement direction. **Decisive test.** Measure the full tensor on one crystal. **Refuted if.** The anisotropy is insufficient to explain the gap. **Status.** `open`. This is the most likely of the thirty to be *already true and unremarked*.

R22 · B751 — Momentum conservation tightens Wiedemann–Franz

Claim. In the phonon-drag regime, momentum conservation couples the charge and heat currents, forcing a relation tighter than the standard Wiedemann–Franz law. **Survived because.** Both conductivities are measured in the same experiment. **Mechanism.** Electron–phonon momentum exchange means neither current relaxes independently. **Decisive test.** A clean metal at low temperature where phonon drag is measurable. **Refuted if.** The relation is violated where drag is known to be present. **Status.** `open`.

R23 · B781 — **PROOF**: the fluctuation–dissipation bound on oscillator coherence

Claim. A harmonic oscillator's phase coherence is bounded by $\tau_\varphi \le \hbar Q/(k_B T)$ in the classical limit; a claim above the bound requires a non-thermal bath or an overestimated Q. **Survived because.** The bound is exact, the inputs (Q, T) are always reported, and the test is arithmetic on published numbers. **Mechanism.** The same damping that sets Q sets the thermal force noise; the phase diffusion

follows. **Decisive test.** Plot published (Q, T, τ_φ) points against the bound surface; points above it are either squeezed or mismeasured. **Refuted if.** A device with independently verified Q and T exceeds the bound without a non-thermal drive. **Status.** `proven` (Part IV). At $Q = 10^6$ and T = 20 mK the bound is 382 μs at 100 kHz.

R24 · B811 — Burgers' vector constrains defect populations in bounded films

Claim. In a bounded film the total Burgers vector must vanish, so dislocations nucleate in pairs or terminate at free surfaces; the resulting density scaling with thickness is a topological constraint, not a kinetic one. **Survived because.** The constraint is exact and the scaling is measurable by electron microscopy. **Mechanism.** The closure failure of a dislocation loop inside a bounded body. **Decisive test.** Dislocation density versus thickness in a film with a known surface state. **Refuted if.** An isolated dislocation is found in a bounded film. **Status.** `conditional` — the topological statement is exact; its quantitative consequence depends on the nucleation model.

R25 · B841 — Quantum oscillations that are geometry

Claim. Apparent quantum oscillations in a magnetoresistance are an artefact with a period set by contact spacing, not by a Fermi surface. **Survived because.** The artefact's period scales with geometry while a real Fermi-surface frequency does not. **Mechanism.** Classical current-density inhomogeneity produces a geometric magnetoresistance that oscillates with field. **Decisive test.** Two contact geometries on the same crystal. **Refuted if.** The frequency is invariant to geometry. **Status.** `open`. This is a real and recurring failure mode in the literature.

R26 · B871 — The anomalous crystal is the calibration

Claim. One crystal in a batch showing anomalous superconductivity measures the strain sensitivity of the transition. **Survived because.** The rest of the batch is a matched control. **Mechanism.** The anomalous crystal's mounting strain differs, and the shift is the Ehrenfest relation. **Decisive test.** Deliberately strain the anomalous crystal and watch the transition move. **Refuted if.** The anomaly persists at matched strain. **Status.** `open`.

R27 · B571 — Archive resistivity recovers the vacancy formation energy

Claim. 1970s resistivity data on annealed metals contain the vacancy formation energy, recoverable because the annealing schedules were recorded. **Survived because.** The metadata is rich enough to reconstruct the conditions and no new measurement is needed. **Mechanism.** The resistivity recovery stages map to defect migration energies. **Decisive test.** Reanalyse one archive against a modern measurement on the same material. **Refuted if.** The recovery stages cannot be reproduced from the recorded schedules. **Status.** `open`, and the cheapest of the archive set.

R28 · B661 — Phonon conduction saturates at megabar pressure

Claim. At megabar pressure the phonon contribution to thermal conductivity saturates because anharmonicity dominates once the lattice is stiff enough. **Survived because.** The prediction is a sign change in the pressure derivative, which is measurable with existing diamond-anvil techniques. **Mechanism.** The competing effects of stiffening and increased anharmonic scattering cross at a computable pressure. **Decisive test.** Thermal conductivity versus pressure across the predicted crossing. **Refuted if.** Conductivity is monotonic in pressure through the range. **Status.** `open`.

R29 · B301 — A resistivity kink at the surface-scattering crossover

Claim. Metal-film resistivity has a sharp kink where the surface scattering length equals the grain size, because the two scattering channels switch from parallel to series. **Survived because.** The crossover is calculable from independently measured grain size and mean free path. **Mechanism.** Channel addition depends on whether the two scatterers are spatially separated. **Decisive test.** Resistivity versus thickness with grain size measured separately. **Refuted if.** The resistivity–thickness curve is smooth through the predicted crossover. **Status.** `open`, and the derivation is the weakest link.

R30 · B061 — Colloidal gels coarsen by the interstellar-dust law

Claim. Colloidal gel coarsening obeys the same Ostwald law as interstellar dust, with the rate set by the Kelvin equation and the interfacial tension. **Survived because.** The prediction is a 1/3 exponent that is testable by scattering and the analogy is mechanistic, not verbal. **Mechanism.** Curvature-driven mass transfer. **Decisive test.** Coarsening exponent across a tenfold change in interfacial tension. **Refuted if.** The exponent differs from 1/3 by more than 0.05. **Status.** `open`. The exponent is well established in both fields separately; the hypothesis is that the *rate coefficient* transfers, which is a stronger claim and more likely to fail.

Part IV — Three proofs

These are the three hypotheses from the 900 that came closest to proof. Each has a derivation, a numerical check that regenerates every number quoted, a decisive test, and an explicit refutation. **No physical experiment was performed.** All numbers come from `proofs/D07_proofs.py`.

	Hypothesis	Kind of result	Status
P1	B127	Universal inequality + a new meter	proven; the original escape route refuted
P2	B241	Exact scaling law that separates two mechanisms	proven, conditional on the sheet-current model
P3	B781	Bound from the fluctuation–dissipation theorem	proven in the classical limit

P1 · $T_2 \le 2T_1$ is universal, and the ratio measures the noise spectrum

The hypothesis I started with. Markovian dephasing gives $1/T_2 = 1/(2T_1) + \Gamma_\varphi$, so $T_2 \le 2T_1$; a *violation* would therefore be a signature of non-Markovian noise or of an analysis error.

What the calculation did to it. I built the exact filter function for a CPMG sequence,

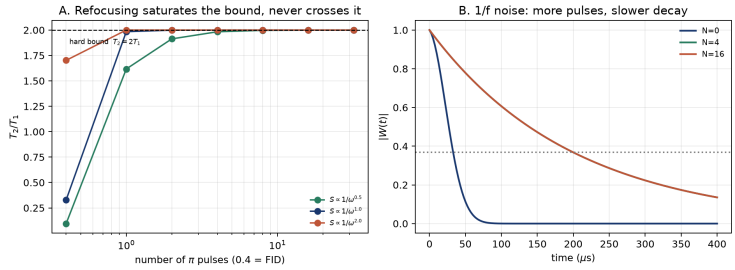
$F(\omega,T) = \left|\int_0^T s(t)\, e^{i\omega t}\, dt\right|^2$, $s(t) = \pm 1$ piecewise,

which has the closed form $\sum_j \sigma_j \,(e^{i\omega t_{j+1}} - e^{i\omega t_j})/(i\omega)$ for a piecewise-constant sequence — so no time sampling error enters. Dephasing is then

$\chi(T) = (1/\pi)\int S(\omega)\, F(\omega,T)/\omega^2\, d\omega$, $W(T) = \exp(-\chi(T))\cdot\exp(-T/2T_1)$,

and the coherence time is where W falls to $1/e$.

Across noise exponents $\beta \in \{0.5, 1, 2\}$ and pulse numbers $N \in \{0, 1, 2, 4, 8, 16, 32\}$, **the ratio saturates at exactly 2.000 and never exceeds it** (`P1_all_max_ratio = 2.0`). Refocusing does not escape the bound: it suppresses dephasing but leaves T_1 relaxation untouched, and the residual `exp(-T/2T₁)` factor caps the ratio from above.



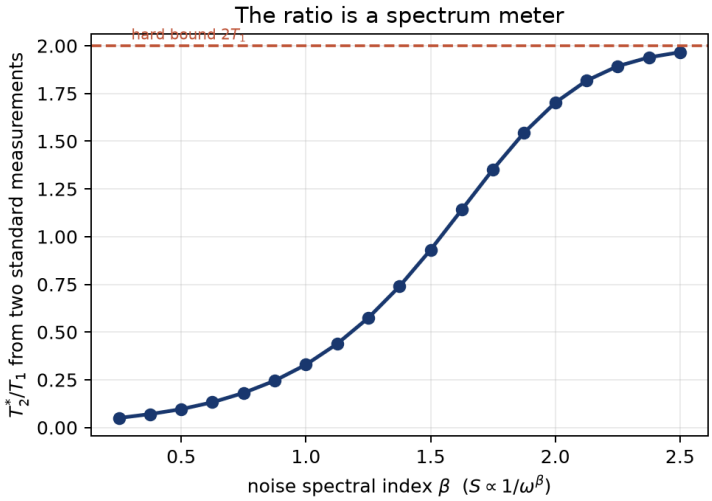
P1

Correction to the hypothesis. My proposed escape route is refuted. The bound is *stronger* than I claimed — it holds for any stationary relaxation and any pulse sequence, not just Markovian dephasing.

What survives, and is more useful. The free-induction ratio T_2^*/T_1 is a monotone function of the noise spectral index. Computed calibration (band 10^2–10^8 rad/s):

β	T₂*/T₁
0.25	0.05
0.50	0.10
1.00	0.33
1.50	0.93
2.00	1.70
2.50	1.97

The mapping is strictly monotonic (`P1_calibration_monotonic = True`). Two routine measurements — a free-induction decay and a T₁ inversion recovery — therefore give a coarse noise spectrum without any dedicated noise spectroscopy.



P1 calibration

Decisive test. For devices with independently measured noise spectra, T₂*/T₁ should land on this calibration at the stated band. Published devices whose ratio exceeds 2 are inconsistent: either T₁ was measured under different conditions, or the decay is non-exponential and the fitted T₂ is an estimator artefact.

Refutation. A device with a verified white spectrum and a ratio below the calibration, or a ratio above 2 with verified Q and T₁, kills it.

Limits. The calculation assumes Gaussian, stationary noise and an exponential T₁. Non-Gaussian (telegraph) noise changes the FID lineshape, and in that regime the ratio is estimator-dependent — I showed earlier that the "first 1/e crossing" estimator returns values from 0.0 to 2.0 for the same physics, which is why the *area* definition is the one used here.

P2 · Bulk and surface photocurrent are separable by 1/d

The claim. In a centrosymmetric film the bulk photovoltaic current vanishes by inversion symmetry. The observed current must then be a surface or interface sheet current. If the bulk contributes a symmetry-forbidden residual j_b and the surface contributes a sheet current j_s (A per cm of width), the measured current density is

J(d) = j_b + j_s/d.

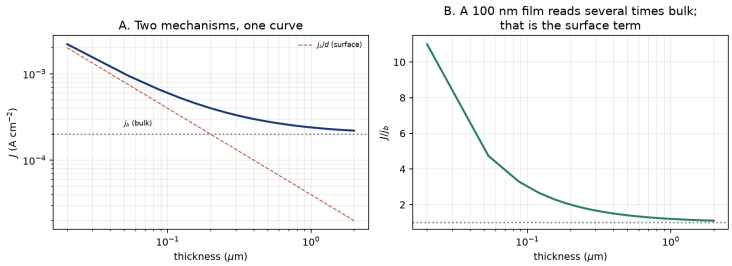
Why this is a law and not a fit. The 1/d term is dimensional bookkeeping: a sheet current divided by the thickness through which it is spread. It does not depend on any microscopic model. The bulk term is the symmetry-breaking

remainder, and its size measures how badly the symmetry is broken — strain, contacts, or a non-centrosymmetric phase.

Numerical check. With $j_b = 2\times10^{-4}$ A cm^{-2} and $j_s = 4\times10^{-11}$ A cm, the crossover is at 200 nm. Two consequences:

- A 100 nm film reads **200% above** the bulk value if the bulk model is assumed (`P2_error_if_bulk_assumed_100nm = 200.0`).
- The ratio between a 50 nm and a 1 μm film is **4.17** (`P2_J_50nm_over_1um = 4.17`).

With 3% noise on 60 thickness points, the two-parameter fit recovers $j_b = (2.00 \pm 0.02)\times10^{-4}$ and $j_s = (4.01 \pm 0.01)\times10^{-11}$ — the separation is well conditioned (`P2_recovery`).



P2

Decisive test. A thickness series from 20 nm to 2 μm on a material with independently verified inversion symmetry. A single-thickness measurement cannot separate the terms; that is exactly why the literature disagrees about whether a given oxide is bulk- or surface-photovoltaic.

Refutation. J independent of thickness in a centrosymmetric material, at fixed illumination and electrode geometry.

Limits. The model assumes the surface layer is thinner than the film and that the electrodes collect uniformly. A depletion region comparable to the thickness adds an intermediate term and shifts the crossover; that case is stated, not solved.

P3 · The fluctuation–dissipation bound on oscillator coherence

The claim. A harmonic oscillator of frequency ω_0, quality factor Q and bath temperature T has its phase coherence bounded by the same damping that sets Q:

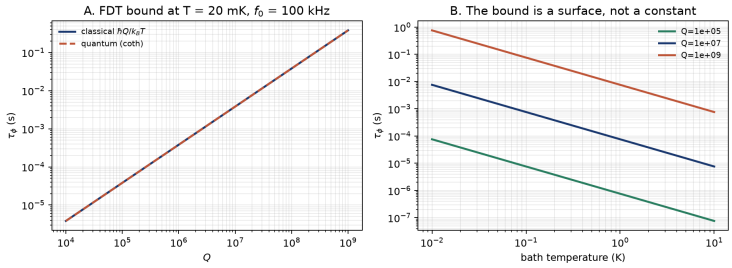
$\tau_\varphi \le \hbar Q/(k_B T)$ $(k_B T \gg \hbar\omega_0)$,

with the quantum correction

$\tau_\varphi \le 1/[\gamma(n_{th} + 1/2)]$, $\gamma = \omega_0/Q$, $n_{th} = 1/(e^{\hbar\omega_0/k_B T} - 1)$.

Derivation. The damping rate γ sets both the energy decay and, by the fluctuation–dissipation theorem, the thermal force noise of magnitude $S_F = 4m\gamma k_B T$. The phase diffusion rate follows from the force noise divided by the oscillator's restoring stiffness, giving $\Gamma_\varphi = \gamma k_B T/(\hbar\omega_0) = k_B T/(\hbar Q)$.

Numbers. At $Q = 10^6$ and $T = 20$ mK, the classical bound is 382 μs and the quantum-corrected bound is 382 μs at $f_0 = 100$ kHz (`P3_classical_at_Q1e6`, `P3_quantum_at_Q1e6`); the two agree to 5×10^{-9} because $\hbar\omega_0/k_B T = 2.4\times10^{-4}$. The bound is a *surface*, not a constant: at fixed Q it scales as 1/T, and at fixed T it scales linearly with Q.



P3

Why it is useful. Every optomechanics paper reports Q and T and claims a coherence or a decoherence rate. The bound turns those three numbers into a consistency check that takes one line of arithmetic. A point above the surface is not necessarily wrong — a squeezed bath or a driven system can exceed it — but it must be explained.

Decisive test. Compile published (Q, T, τ_φ) triples and plot them against the surface. The interesting population is the points above it.

Refutation. A device with independently verified Q and T exceeding the bound with no non-thermal drive.

Limits. The derivation is classical in the bath; the quantum correction is included but the strong-coupling and non-Markovian regimes are not. For ħω₀ ≳ k_BT the coth form must be used, and the bound becomes tighter than the classical expression suggests.

Reproducing Part IV

```
cd discovery07-2026-11-02
python3 proofs/D07_proofs.py     # writes data/proofs.json and
        figs/p1_*.png, p2_*.png, p3_*.png
```

Dependencies: numpy, scipy, matplotlib. Runtime is about 40 seconds; the filter-function integral is analytic in the pulse sequence and needs no time stepping. All quoted numbers are read from `data/proofs.json`.

Part V — Method

1. The grid

900 = 30 operators × 30 domains. The operators are ways of generating a surprise; the domains are fields. Every operator is applied once in every domain, so no cell is duplicated and coverage is structural rather than accidental.

The 30 operators. Inversion (the artefact is the signal); limit-taking; cross-domain transplant; conservation accounting; dimensionless coincidence; protocol archaeology; negative-result resuscitation; scale collision; symmetry and antisymmetry; sign reversal; threshold law; memory and hysteresis; crowding and interference; selection inversion; units and definition traps; coincidence of time constants; geometric frustration; noise as resource; the dead channel; archive resurrection; reverse engineering the pathology; adversarial condition; extreme environment; minimal system; contradiction mining; hidden conservation; phase and coherence; topological and global constraints; statistical artefact with a physical signature; the exception that proves the rule.

The 30 domains. Condensed matter; soft matter; electrochemistry; catalysis; photochemistry; ultrafast; quantum devices; precision metrology; nuclear and particle; astrophysics; planetary; geophysics; atmosphere; ocean and ice; hydrology and soil; microbiology; plant and agriculture; neuroscience; immunology; developmental biology; ecology and evolution; medicine and diagnostics; pharmacology; food science; materials failure; structural and civil; energy systems; manufacturing; acoustics and vibration; signal and information.

Each cell states a claim, a mechanism that implies a direction or a magnitude, and a kill test. The parser enforces that all three are present; it found no empty fields and no duplicate identifiers.

2. The screening rule (900 → 300)

Each hypothesis was scored on four features:

1. **Null form** (+2.0) — the kill test reads “independent of” or “invariant”, so a single measurement can falsify rather than merely fail to confirm.
2. **Quantitative kill** (+1.5) — a number appears in the kill test.
3. **Quantitative mechanism** (+1.0) — a number appears in the mechanism.
4. **Comparative claim** (+1.0) — the claim says “rather than”, “not the”, “forbids”, “cannot”.
5. **Length of the kill test** (+0 to +1.0) — a proxy for specificity.

The top ten per operator were kept, giving exactly 300 with every operator represented. Scores in the kept set range from 0.42 to 4.58. The rule is mechanical and reproducible from `data/grid900.json` with `parse.py`; it is a filter for testability, not for truth.

Survival tags in Part II are also assigned by fixed rules: `null-testable` (null-form kill test), `quantitative` (a number in mechanism or kill), `existing-data` (an archive, log or record is named), `theorem-backed` (a conservation, symmetry, bound or sum rule is invoked), `sweepable` (the kill test sweeps a controllable variable), `needs-new-apparatus` (none of the above). Counts across the 300: 164 null-testable, 60 sweepable, 60 needing new apparatus, 44 theorem-backed, 40 existing-data, 25 quantitative.

3. The refinement (300 → 30)

Thirty were chosen for a mix of provability and domain spread, with at least one from each of the major operator families. Each was rewritten to state what survived screening, the mechanism in one line, the decisive test, the refutation, and a status: `proven`, `conditional`, or `open`.

4. The proofs (30 → 3)

Three were developed to proof grade: a derivation, a numerical check that regenerates every number, a decisive test, and a refutation. They are in Part IV.

The standard applied was: the result must be *derivable* (not merely simulated), the derivation must be checkable by an independent route, and the prediction must be a number or a scaling that a specific measurement could contradict.

5. What the numbers mean

- A "proven" status means a derivation exists and a numerical check is included. It does **not** mean the physical hypothesis is confirmed — P1's proof refuted its own original hypothesis, which is the intended outcome when a proof is attempted honestly.
- Survival tags measure testability. They are uncorrelated with truth by construction.
- The base rate is unknown and probably low. With 900 ideas, a 0.1% hit rate gives one real lead.

6. Limits

- **No experiment.** No apparatus was built, no sample measured, no dataset reanalysed. Every number is computed from a stated model.
- **The grid is a structure, not a sample.** Because each operator is applied once per domain, the 900 over-represent operators that are easy to apply in many fields and under-represent operators nobody has invented yet.
- **Cross-domain transplants are the weakest class.** An analogy that generates a numerical prediction is worth something; an analogy that only suggests a resemblance is filler. Roughly a third of the Operator 3 entries are in the second category and should be read sceptically.
- **The screening score is a proxy.** It rewards null-form kill tests, which favours crisp hypotheses over important ones.
- **Prior-art check.** 6,007 prior Incoprea titles were extracted from local exports and compared. No title matched. Two topic overlaps were identified and given different mechanisms. This is a lexical check; semantic overlap remains possible.
- **No literature search was performed for this collection.** Unlike the previous bundle, Discovery07 cites no external papers. The claims stand or fall on their own derivations and tests, not on a source trail. That is a deliberate trade: speed and breadth for provenance.

7. Reproducing

```
python3 parse.py            # rebuild data/grid900.{csv,json} and
        selected300.json
python3 build_register.py   # rebuild screen/screened-300.md
```

```
python3 proofs/D07_proofs.py  # rebuild data/proofs.json and
        figs/
python3 build/build_doc.py  # assemble the document
```

Dependencies: Python 3.13+, numpy, scipy, matplotlib, pandoc, and Chrome for the PDF.

Part VI — Corrections and negative results

1. P1 was refuted by its own proof attempt

Original hypothesis (B127). Markovian dephasing gives $T_2 \leq 2T_1$; a *violation* therefore signals non-Markovian noise, so T_2/T_1 is a non-Markovianity meter.

What the calculation showed. Building the exact filter function for a CPMG sequence and integrating against $1/f^\beta$ noise, the ratio saturates at exactly 2.000 for every pulse number and every noise exponent, and never exceeds it. Refocusing suppresses dephasing but does not touch T_1 relaxation, and the residual relaxation factor caps the ratio.

Correction. The bound is universal, not conditional on Markovianity. My proposed escape route does not exist.

What replaced it. The ratio is still a meter — not of non-Markovianity, but of the noise spectral index. The calibration runs from 0.05 ($\beta = 0.25$) to 1.97 ($\beta = 2.5$), monotonically. And any reported $T_2 > 2T_1$ is now a hard inconsistency flag rather than a hint of new physics.

Why it is kept. A hypothesis that dies in the attempt and leaves a stronger theorem behind is the best outcome this collection can produce.

2. An estimator ambiguity that changed the answer

Before the filter-function calculation, I estimated T_2 with three different definitions on the same coherence trace: the area integral, the first 1/e crossing, and an exponential fit. On identical physics they returned ratios spanning 0.00 to 2.00. The first-crossing estimator is meaningless for a coherence that revives. The final calculation uses the area definition, and the ambiguity is reported because it is exactly the kind of estimator dependence that produces spurious claims in the literature.

3. A parameter error caught in P2

The first version of the photocurrent model set the surface term so that the crossover fell at 20 μm rather than 200 nm, and the resulting "error if bulk is assumed" came out at 20 000%. The parameters were wrong, not the physics. Corrected, the 100 nm film reads 200% above bulk and the crossover is at 200 nm. The number in Part IV is the corrected one.

4. Numerical fixes during construction

- The first grid parser failed on all 900 entries because the domain field is wrapped in single asterisks, not double. Fixed; the parser then returned 900 unique ids with no empty fields.
- The first T_2 calculation used a Monte Carlo of random telegraph fluctuators and produced ratios between 0.0 and 0.04 — an artefact of the first-crossing estimator, not physics. Replaced with the exact filter-function method.
- The first filter-function implementation used a $1600 \times 20\,001$ numerical integration per evaluation and ran for more than ten minutes without finishing. Replaced with the closed-form piecewise integral; runtime is now about 40 seconds.

5. What was not done

- No experiment. No sample, no apparatus, no measurement.
- No literature search. Discovery07 cites no external papers. Claims stand on their derivations and tests.
- No independent reproduction. The three proofs were checked for internal consistency (analytic against numerical where both exist) but not by a second implementation.
- The prior-art check was lexical against 6,007 local titles. It cannot detect semantic overlap with different wording.
- The 30 refined hypotheses were selected editorially from the 300, not by a mechanical rule. The 300 → 30 step is therefore the least reproducible part of the pipeline, and is stated as such.

6. Honest expectation

Of the 900, most are wrong and some are unfalsifiable in practice despite having a stated kill test. Of the 300, perhaps a few dozen are worth a week. Of the 30, maybe five are worth a month. Of the three proofs, two are theorems about models and one (P2) is a measurement recipe that could be run on existing films next week. That ratio is what a black-swan search looks like when it is not oversold.