Why Billiard Balls, Soldier Crabs, and Quantum Computers Deserve the Same Research Funding

On the Equivalence of Continuous-Variable Computational Paradigms

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Abstract

We examine the foundational assumption shared by quantum computing, classical analog computing, billiard-ball computing, and biological computing (soldier crabs): that continuous physical variables can be controlled with sufficient precision to perform useful computation. We introduce concrete error-correction schemes for billiard-ball systems (BBEC) and crab-based systems (CEC), demonstrate that their failure modes are structurally identical to those facing quantum error correction (QEC), and show that the reasons we immediately recognize BBEC and CEC as unworkable apply with equal force to QEC at scale. We present a formal framework for comparing precision requirements across paradigms, address the linearity objection by showing that decoherence reintroduces effective chaos, and catalog 30 years of unfulfilled milestones in quantum computing. We conclude that the precision requirements for useful quantum computation are, by all available experimental evidence, physically unachievable, and that the quantum computing program rests on the same unfounded assumption as the billiard-ball computer: that continuous variables in physical matter can be controlled with arbitrary precision.

Keywords: quantum computing, analog computation, P vs NP, billiard-ball computer, soldier crab logic gates, quantum error correction, decoherence, correlated noise, computational skepticism

1 Introduction

Quantum computing has attracted billions of dollars in investment, hundreds of thousands of academic publications, and the sustained attention of major technology corporations including IBM, Google, Microsoft, and Intel. The central promise is that quantum superposition and entanglement enable exponential speedups for certain computational problems, most notably integer factorization via Shor's algorithm [1] and unstructured search via Grover's algorithm [2].

Despite over three decades of research, the largest integer reliably factored by a gate-based implementation of Shor's algorithm on physical quantum hardware remains $21 = 3 \times 7$ [3], and even this achievement relies on circuit compilation that exploits prior knowledge of the answer [4]. The factorization of 15, frequently cited as a milestone [5], employed on the order of 300 physical operations rather than the thousands required for a general-purpose implementation. Modern estimates for the gate count range from $O(n^3)$ [6] to $72n^3$ [7]; for RSA-2048, this yields between 2.6×10^9 and 6.2×10^{11} gates.

In this paper, we examine the foundational assumption that unites quantum computing with several other computational paradigms universally regarded as physically unrealizable. Our central contribution is twofold: (1) we construct explicit error-correction schemes for billiard-ball and crab-based computers, show that they fail for identifiable physical reasons, and demonstrate that each failure mode has a precise quantum analog; (2) we provide a formal framework for comparing precision requirements, showing that the quantum computer's control complexity exceeds the billiard-ball computer's by $\sim 10^{1200}$.

2 Thirty Years of Unfulfilled Milestones

Before proceeding to theoretical arguments, we catalog the empirical record.

2.1 The ARDA Roadmap

In the early 2000s, a panel of distinguished experts convened by the Advanced Research and Development Activity (U.S. intelligence community) established a roadmap for quantum computing [27]. The goal for 2012 was: "requires on the order of 50 physical qubits" and "exercises multiple logical qubits through the full range of operations required for fault-tolerant quantum computation." As Dyakonov noted [11], by the end of 2018 this goal had still not been demonstrated.

2.2 D-Wave Systems

D-Wave Systems, founded in 1999, has operated for over 25 years without demonstrating a proven quantum speedup on any practical problem. Their quantum annealing approach has been repeatedly shown to offer no clear advantage over classical optimization heuristics on equivalent hardware [8].

2.3 "Quantum Supremacy"

In 2019, Google claimed "quantum supremacy" with its Sycamore processor: a 53-qubit device that performed a specific sampling task in 200 seconds, compared to an estimated 10,000 years on a classical supercomputer [9]. IBM responded within days, arguing the task could be completed classically in 2.5 days with sufficient storage [10]. The task had no practical application.

2.4 The Nanotech Precedent

The quantum computing trajectory mirrors that of molecular nanotechnology in the 1990s–2000s. K. Eric Drexler promised molecular assemblers and artificial life forms. U.S. Congressional hearings were held in 2003 and 2005. Russia built a nanotech park (Rusnano). A trillion-dollar nanotech economy was projected. The result was zero functional molecular assemblers. A generation of chemists and materials scientists invested their early careers in a field that produced no deliverables.

2.5 Pattern Recognition

The pattern is consistent across speculative technologies: elegant theory $\rightarrow$ generous funding $\rightarrow$ confident predictions $\rightarrow$ stagnation when physical reality refuses to cooperate. Fusion power ("30 years away" since the 1970s), autonomous vehicles ("2 years away" since 2015), and molecular nanotech all share this trajectory. Quantum computing, now in its fourth decade, fits the pattern precisely.

3 Empirical Refutations of Flagship Claims

The quantum computing industry rests on two flagship experimental claims: IBM's "quantum utility" (2023) and Google's "quantum supremacy" (2019). Both have been comprehensively refuted by classical computation. We document these refutations in detail, as they constitute the strongest available empirical evidence that quantum computers provide no practical advantage, and may never do so.

3.1 The Collapse of IBM's "Quantum Utility" Claim

In June 2023, IBM published a paper in *Nature* [32] claiming that their 127-qubit Eagle processor had performed a simulation of the transverse-field Ising model on a heavy-hexagon lattice that was "beyond the reach of brute-force classical simulation." IBM's marketing apparatus and uncritical press coverage promoted this as evidence of "quantum utility," the threshold at which quantum computers begin to outperform classical ones on practically relevant tasks.

The claim survived approximately three months before being demolished by multiple independent research groups using approximate classical methods.

Tindall et al. [33] demonstrated that tensor network methods with belief propagation could simulate the same Ising model on the heavy-hexagon lattice more accurately than IBM's quantum processor, at a fraction of the computational cost. Their classical simulation did not merely match the quantum result; it exceeded it in fidelity. The quantum computer, with its endemic noise and error rates, produced results that were strictly inferior to a classical approximation algorithm.

Begušić & Chan [34] obtained a starker result: their sparse Pauli dynamics algorithm, running on a single core of a laptop, outperformed IBM's 127-qubit quantum processor by orders of magnitude in both speed and accuracy. The classical algorithm required no cryogenic cooling, no dilution refrigerator, no multi-million-dollar fabrication facility; just a commodity processor executing well-designed linear algebra. This result was published in *Science Advances*.

Orús et al. [35] extended this to IBM's entire processor lineup: they showed that 2D tensor networks (gPEPS) can efficiently and accurately simulate not only Eagle (127 qubits) but also Osprey (433 qubits) and Condor (1,121 qubits), IBM's largest processors. The classical simulation scales gracefully to system sizes that IBM has marketed as being beyond classical reach.

Observation 1. *IBM's flagship quantum processor, the centerpiece of billions of dollars in investment and years of engineering effort, was outperformed on its own benchmark by a laptop. The classical methods are faster, cheaper, more accurate, and more scalable. If this is "quantum utility," the word "utility" has been redefined beyond recognition.*

3.2 The Collapse of Google's "Quantum Supremacy"

In October 2019, Google published in *Nature* [9] the claim that their 53-qubit Sycamore processor had achieved "quantum supremacy": performing a random circuit sampling task in 200 seconds that would take the world's most powerful classical supercomputer an estimated 10,000 years. IBM disputed this within days [10], estimating the classical time at 2.5 days with sufficient storage.

The situation deteriorated further for Google.

Pan, Zhang et al. [36] (Chinese Academy of Sciences) reformulated the sampling problem as a 3D tensor network contraction and exploited the low fidelity of Sycamore's output (approximately 0.2%) to achieve classical simulation using 512 GPUs in a matter of hours. They estimated that on a full-scale supercomputer, the computation would complete in tens of seconds, approximately 10^{10} times faster than Google's original estimate for classical simulation. This result was published in *Physical Review Letters*. The gap between Google's claimed 10,000-year advantage and reality (seconds) represents one of the largest overestimates in the history of computational science.

Rong Fu et al. [37] (Shanghai AI Laboratory) further demonstrated that a classical system could not only solve the same sampling problem faster than Sycamore, but could do so with lower energy consumption. Google itself subsequently conceded that classical simulation of 53 qubits would require only approximately 6 seconds on the Frontier supercomputer.

Kalai & Kindler [38] provided a detailed mathematical critique of Google's fidelity estimates and methodology, arguing that the claimed computational advantage rests on questionable statistical assumptions and that the samples produced by Sycamore may not constitute evidence of quantum computational advantage at all.

Observation 2. *Google's "quantum supremacy," the single most celebrated claim in the history of quantum computing, evaporated within three years. The claimed* $10^{10}\times$ *advantage turned out to be a* $10^{10}\times$ *overestimate of classical difficulty. The task had no practical application. The quantum computer's output had 0.2% fidelity. Classical computers ultimately solved the problem faster, cheaper, and more accurately.*

3.3 The Commodore 64 Verdict

The definitive commentary on the state of quantum computing was delivered not in *Nature* or *Physical Review Letters*, but at SIGBOVIK 2024, the annual conference of the Association for Computational Heresy [39].

An anonymous researcher implemented the same Trotterized Ising model simulation that IBM claimed required a 127-qubit quantum processor on a **Commodore 64**: a home computer from 1982 with a 1 MHz MOS 6510 processor, 64 KB of RAM (of which the program used 15 KB), and no floating-point unit. The implementation, dubbed "Qommodore 64," used the sparse Pauli dynamics method in approximately 2,500 lines of 6502 assembly language and was loaded from a cartridge.

The Commodore 64 is approximately 300,000 times slower than a modern laptop per data point. It is, however, significantly faster than IBM's quantum processor on the same benchmark, produces results without the quantum processor's endemic noise, and does not require cooling to 15 millikelvin. The author's computation ran at room temperature, powered by a standard wall outlet, on hardware that originally retailed for $595 in 1982.

The author offered to provide source code in one of three formats: a manuscript on papyrus, a slideshow of blurry screenshots on a VHS cassette, or personal dictation over the telephone.

Observation 3. *A 42-year-old home computer with 64 kilobytes of memory outperforms a state-of-the-art quantum processor representing billions of dollars of investment. The quantum computing industry has spent three decades and tens of billions of dollars to build machines that lose to hardware available at garage sales. The burden of demonstrating "quantum advantage" has not been unmet; it has been inverted. We propose the term* ***"quantum disadvantage"*** *for the consistent empirical observation that quantum processors are slower, less accurate, and more expensive than classical alternatives on every task where direct comparison has been attempted.*

3.4 Summary: The Empirical Record

In every case where a quantum computing claim has been subjected to rigorous classical comparison, the classical system has won decisively. The quantum computing industry has not produced a single unrebutted demonstration of practical advantage on any problem of real-world relevance. This is the empirical record, and it should be the starting point of any honest assessment.

Table 1: Flagship quantum claims vs. classical reality

Claim	Quantum system	Classical refutation	Advantage
IBM "utility" (2023)	Eagle, 127 qubits, cryo	Single laptop core	Faster, more accurate
Google "supremacy" (2019)	Sycamore, 53 qubits	512 GPUs (hrs); supercomputer (sec)	$10^{10}\times$ faster than claimed
IBM Ising (2023)	Condor, 1121 qubits	gPEPS tensor networks	Scales to all IBM chips
IBM Ising (2023)	Eagle, 127 qubits	Commodore 64, 1 MHz	1982 hardware wins

4 The Continuous Variable Assumption

The state of an N-qubit quantum computer is described by a normalized vector in a 2^N-dimensional complex Hilbert space:

$$|\psi\rangle = \sum_{i=0}^{2^N-1} \alpha_i |i\rangle, \quad \sum_{i=0}^{2^N-1} |\alpha_i|^2 = 1 \tag{1}$$

where each $\alpha_i \in \mathbb{C}$ is a *continuous* variable. A quantum gate is a unitary transformation $U \in \mathbb{C}^{2^N \times 2^N}$:

$$|\psi'\rangle = U|\psi\rangle \tag{2}$$

For a classical N-bit computer, the system occupies exactly one of 2^N states. Controlling it requires specifying N discrete values. For a quantum computer, the system occupies a superposition of all 2^N states. Controlling it requires specifying 2^N continuous complex amplitudes.

Table 2: Exponential growth of state space

N qubits	2^N amplitudes	comparison
10	$\sim 10^3$	thousand
50	$\sim 10^{15}$	quadrillion
100	$\sim 10^{30}$	$>$ atoms on Earth
270	$\sim 10^{81}$	$\approx$ particles in universe
4,000	$\sim 10^{1204}$	$10^{1124}\times$ universe
8,195	$\sim 10^{2467}$	$10^{2387}\times$ universe

As Dyakonov observed [11]: a useful quantum computer must process a set of continuous parameters larger than the number of subatomic particles in the observable universe. At this point, a hardheaded engineer loses interest.

5 Classical Analog Computational Equivalents

5.1 The Protractor Computer

If one could inscribe and measure an angle with infinite precision, one could encode an arbitrary real number in a single physical degree of freedom, yielding P=NP [15]. This result is universally recognized as nonphysical, because matter is not infinitely continuous and measurement precision is bounded by fundamental limits.

Most complexity theorists understand this and dismiss protractor P=NP without hesitation. Quantum computing, however, rests on the same foundational assumption, namely that continuous variables in physical matter can be controlled with arbitrary precision, yet receives billions in funding. As Dyakonov has repeatedly emphasized [11, 13], the qubit is not a binary digit; it is a continuous variable on the Bloch sphere, specified by two real parameters (θ, ϕ). Controlling N qubits requires controlling 2^N complex amplitudes to high precision. This is the protractor problem scaled to exponentially many degrees of freedom.

The distinction is worth formalizing. A single protractor encodes one real number in one continuous degree of freedom. A quantum computer with N qubits encodes 2^N complex amplitudes, each a continuous variable. If protractor computation is nonphysical because one continuous parameter cannot be controlled with sufficient precision, then quantum computation, which requires controlling exponentially many such parameters simultaneously, faces a strictly harder version of the same problem. The rejection of protractor P=NP and the acceptance of quantum speedup are logically inconsistent positions.

5.2 The Billiard-Ball Computer

Fredkin and Toffoli [16] showed that reversible computation can be performed by elastic collisions of idealized billiard balls. With continuous-valued initial conditions, NP-hard problems become solvable in polynomial time [17]. The billiard-ball computer is Turing-complete and, in the idealized case, thermodynamically reversible.

In practice, deterministic chaos destroys the computation after approximately 10 collisions. Each collision amplifies positional uncertainty exponentially (Lyapunov instability), and within a small number of interactions the trajectories bear no relation to the intended computation. No amount of engineering refinement can overcome this: the sensitivity to initial conditions is intrinsic to the dynamics. A billiard-ball computer attempting RSA-2048 would require controlling initial positions to a precision exceeding 10^{-1000} meters, a length scale many orders of magnitude below the Planck length ($\sim 10^{-35}$ m).

The analogy to quantum computing is direct. Dyakonov [13, 14] has argued that the quantum computer is fundamentally an analog machine employing a physical system with continuous degrees of freedom, and that quantum computing should be compared with analog classical computing. For an N-qubit quantum computer, one must control, transform, and read out 2^N complex amplitudes to a very high degree of precision. A classical analog computer with N oscillators that must be precisely initialized, precisely controlled, and individually read out, to the point where the computation could be run in reverse, would be immediately recognized as physically impossible. The quantum computer demands this and more: the state space is not merely large but exponentially larger than any classical analog system of comparable physical size.

5.3 The Soldier Crab Computer

Gunji et al. [18] demonstrated that swarms of soldier crabs (*Mictyris longicarpus*) implement Boolean logic gates when channeled through appropriately shaped corridors. When two swarms collide at a junction, the merged swarm follows one of two output channels depending on the relative swarm sizes, implementing AND and OR operations. Since $\{\mathrm{AND}, \mathrm{OR}, \mathrm{NOT}\}$ is functionally complete, crabs can in principle compute any Boolean function.

No theorem forbids crabs from computing. The gate fidelity reported by Gunji et al. was approximately 80%, comparable to early quantum gate fidelities. The failure modes are environmental (wind, temperature, predator shadows) and biological (fatigue, death, behavioral variation).

These are precisely analogous to the failure modes of quantum hardware: environmental noise, decoherence, and device-to-device variation. The crab computer is rejected not because of a formal impossibility proof but because the engineering challenges are self-evidently insurmountable at scale. The same judgment, applied consistently, would lead to identical conclusions about quantum computing.

5.4 The Soap Bubble Computer

Soap films minimize surface area by physical dynamics, thereby solving instances of the Steiner tree problem (NP-hard) in analog [19]. The film settles into a local energy minimum, which may approximate the global optimum. Similar analog optimization occurs in other physical systems: protein folding, crystal annealing, and fluid dynamics.

The limitations are characteristic of all analog computation: the system finds local rather than global minima, measurement precision limits the extractable accuracy, and the physical substrate is fragile (soap films rupture, crystals crack, fluids evaporate). These limitations are not engineering failures; they reflect fundamental physical constraints on extracting computational work from continuous systems. Quantum annealing (D-Wave) faces structurally identical limitations: settling into local minima, limited precision, and decoherence destroying the quantum state before the global optimum is reached.

6 Error Correction for Classical Analog Systems

This section constitutes our central novel contribution. We construct explicit error-correction schemes for billiard-ball and crab-based computers, modeled on quantum error correction, and analyze their failure modes.

6.1 Billiard-Ball Error Correction (BBEC)

We propose BBEC by direct analogy with the surface code.

6.1.1 Architecture

A **logical ball** is a single ball performing useful computation, surrounded by d^2 **syndrome balls** arranged in a 2D grid (where d is the code distance). After each collision:

1. Measure positions of all syndrome balls ("syndrome extraction")
2. Compute deviation of logical ball from intended trajectory ("decoding")
3. Launch a **correction ball** at the calculated angle and velocity to nudge the logical ball back on course ("recovery")

For a code distance d, BBEC can tolerate up to $\lfloor (d-1)/2 \rfloor$ independent single-ball deviations per correction cycle, exactly analogous to QEC.

6.1.2 Threshold Theorem for BBEC

By analogy with the quantum threshold theorem, we state:

Proposition 1 (BBEC Threshold, Informal)**.** *If the per-collision position error δ is below a threshold δ_{th}, and errors on different balls are independent and identically distributed, then arbitrarily long billiard-ball computation is possible at the cost of a polynomial overhead in the number of balls.*

This statement is *mathematically valid* under the stated assumptions, just as the quantum threshold theorem is mathematically valid under its stated assumptions. The question is whether the assumptions can be physically satisfied.

6.1.3 Why BBEC Fails

Failure Mode 1: Measurement backaction. Measuring a ball's position requires physical interaction (e.g., bouncing a photon off it). This perturbs the ball's momentum. The measurement precision Δx and the momentum disturbance Δp satisfy the uncertainty relation $\Delta x \cdot \Delta p \geq \hbar/2$. Even classically, optical measurement of a small ball at precision $\delta \sim 10^{-5}$ imparts non-negligible radiation pressure.

Quantum analog: Syndrome measurement in QEC requires ancilla qubits and entangling gates, each of which introduces noise. The measurement is not free.

Failure Mode 2: Correlated noise. All balls roll on the same table. Table vibrations, surface imperfections, and air currents affect nearby balls simultaneously. If the table has a slight systematic tilt of angle θ, *all* balls drift in the same direction. This correlated deviation is invisible to syndrome extraction (which detects differential deviations) and accumulates linearly with time.

Quantum analog: All qubits share an electromagnetic environment. Systematic calibration errors, magnetic field gradients, and crosstalk introduce correlated noise invisible to syndrome measurements designed for independent errors.

Failure Mode 3: Chaos amplifies uncorrected residuals. After correction, a residual error δ_{res} remains. In a chaotic system with Lyapunov exponent λ, this residual grows as $\delta_{\text{res}} \cdot e^{\lambda t}$. After k correction cycles of duration τ:

$$\delta_{\text{total}} \sim \delta_{\text{res}} \cdot \sum_{j=0}^{k} e^{\lambda j \tau} = \delta_{\text{res}} \cdot \frac{e^{\lambda(k+1)\tau} - 1}{e^{\lambda\tau} - 1} \tag{3}$$

For $\lambda\tau > 0$, this diverges exponentially. Correction must be faster than the Lyapunov time $1/\lambda$, which for hard-sphere collisions is on the order of the collision time itself. This means correction must occur during each collision, which is a physical impossibility.

Quantum analog: Decoherence introduces exponential decay of off-diagonal density matrix elements with rate $1/T_2$. QEC cycles must be faster than T_2. For current hardware, $T_2 \sim 10^{-6}$–10^{-3} s, and QEC cycle times are $\sim 10^{-6}$ s, leaving zero margin.

Failure Mode 4: Recursive overhead. Correction balls are also physical objects subject to the same errors. Correcting their trajectories requires second-order correction balls, which require third-order corrections, etc. The overhead converges only if $\delta < \delta_{\text{th}}$ *strictly*, with margin. At the threshold boundary, the recursion diverges.

Quantum analog: QEC circuits require gates that themselves err. The threshold theorem guarantees convergence only for $\varepsilon_{\text{gate}} < \varepsilon_{\text{th}}$ with margin. Current hardware operates at or near the threshold boundary.

6.2 Crab Error Correction (CEC)

6.2.1 Architecture

A **logical crab-flow** consists of n crabs moving in formation (the "data flow"). It is flanked by m **syndrome crab-flows** on each side, moving in parallel:

1. After each junction (gate), observe whether syndrome flows have deviated from expected paths ("syndrome extraction")

2. If deviation detected, release a **correction crab-flow** perpendicular to the logical flow to nudge it back ("recovery")

6.2.2 Why CEC Fails

Failure Mode 1: Observer effect. Crabs respond to the shadow and vibrations of the observer. Measuring a crab-flow's trajectory perturbs it. This is not a quantum effect but a biological one, though it is structurally identical to measurement backaction.

Quantum analog: Measurement backaction via entanglement with ancilla qubits.

Failure Mode 2: Shared environment. All crabs are on the same beach. Wind, waves, temperature, and predator shadows affect all flows simultaneously. A gust of wind is the crab equivalent of a correlated electromagnetic pulse.

Quantum analog: Shared cryogenic environment, electromagnetic crosstalk.

Failure Mode 3: Fatigue and death. Crabs have finite energy reserves and finite lifespans. After prolonged computation, individual crabs slow down, change direction randomly, or die. This is decoherence by another name: the crab's internal state ("phase") loses coherence with the computational state it is supposed to represent.

Quantum analog: T_1 relaxation (energy decay), T_2 decoherence (phase randomization).

Failure Mode 4: Non-reproducibility. No two crabs are identical. Size, speed, and behavioral responses vary. This inherent heterogeneity introduces systematic errors that cannot be calibrated away because each crab is unique.

Quantum analog: Qubit-to-qubit frequency variation, fabrication inhomogeneity in Josephson junctions.

6.3 The Structural Isomorphism

Table 3: Failure mode correspondence

Failure mode	Classical (BBEC/CEC)	Quantum (QEC)
Measurement backaction	Photon pressure / crab startling	Ancilla entanglement noise
Correlated noise	Table vibration / wind on beach	EM crosstalk / shared cryostat
Coherence loss	Friction, air drag / crab fatigue	T_1, T_2 decoherence
Error amplification	Lyapunov divergence	Decoherence cascade
Recursive overhead	Correction balls also err	Correction gates also err
Fabrication variation	No two balls/crabs identical	Junction inhomogeneity

Observation 4. *Every failure mode that makes BBEC and CEC obviously unworkable has a precise structural analog in QEC. The difference is not in the structure of the problem but in the language used to describe it: "Lyapunov exponent" versus "decoherence rate," "table vibration" versus "electromagnetic crosstalk," "crab fatigue" versus "T_1 relaxation." The physics differs; the engineering impossibility is isomorphic. QEC avoids immediate dismissal only because the impossibility is wrapped in sufficiently abstract formalism. Remove the formalism, and the problem is the same.*

7 Addressing the Linearity Objection

The strongest counterargument to our comparison is that quantum mechanics is *linear*: errors decompose into a discrete Pauli basis $\{I, X, Y, Z\}^{\otimes N}$, enabling syndrome-based detection. Classical chaotic systems are nonlinear: small errors grow exponentially, and no analogous error basis exists.

We acknowledge this distinction. It is the theoretical foundation of QEC and constitutes a genuine qualitative difference between quantum and classical analog computation.

However, we argue that *decoherence nullifies this advantage in practice*:

1. A qubit coupled to an environment evolves under $H = H_S + H_E + V$, where V couples system and environment [21].
2. Tracing over the environment yields non-unitary reduced dynamics (Lindblad master equation) with coherence decay time T_2.
3. Current $T_2 \sim 10^{-6}$–10^{-3} s. RSA-2048 factoring requires $\sim 10^3$–10^4 s with optimistic parallelism.
4. The decoherence gap: $T_{\text{compute}}/T_2 \sim 10^6$–$10^{10}$.

The linearity of quantum mechanics provides the theoretical framework for error discretization. Decoherence, the coupling to a high-dimensional uncontrollable environment, provides the practical framework for its failure. Mathematically, the Lindblad equation introduces effective nonlinearity (irreversibility) into the reduced dynamics, analogous to the effective chaos introduced by friction and air resistance in the billiard-ball system.

To put it differently: in a perfectly isolated quantum system, QEC works. In a perfectly frictionless billiard table, BBEC also works. Neither perfect isolation nor perfect frictionlessness is physically achievable. The question is not whether the math works in the ideal case (it does, for both) but whether the gap between ideal and real can be bridged. For billiard balls, everyone immediately sees that it cannot. For qubits, the same conclusion requires more sophisticated reasoning, but the conclusion is the same, and arguably worse: the billiard-ball computer requires controlling $\sim 10^4$ continuous variables, while the quantum computer requires controlling $\sim 10^{1204}$. The quantum system is not as impractical as the billiard-ball computer; it is 10^{1200} times *more* impractical.

8 The Correlated Noise Problem

QEC codes assume independent, identically distributed errors. We now show concretely how correlated noise defeats error correction.

Example 1 (Systematic Calibration Error)**.** *Consider a surface code on a $d \times d$ grid of physical qubits, with $d = 7$ (the minimum for useful error suppression). Suppose each single-qubit rotation gate has a systematic over-rotation of $\theta_{\text{err}} = 10^{-4}$ radians, identical across all qubits (due to shared control electronics).*

Under independent noise at rate $\varepsilon = 10^{-3}$, the surface code with $d = 7$ suppresses logical errors to $\varepsilon_L \sim (c \cdot \varepsilon)^{\lfloor d/2 \rfloor} \approx (10^{-2})^3 = 10^{-6}$.

Under correlated noise with systematic component $\theta_{\text{err}} = 10^{-4}$, all qubits rotate in the same direction. The syndrome measurements, designed to detect differential *errors, show no anomaly: all qubits have shifted identically. The logical qubit accumulates an undetected phase error of θ_{err} per gate cycle. After $T = 10^9$ cycles:*

$$\theta_{\text{total}} = T \cdot \theta_{\text{err}} = 10^9 \cdot 10^{-4} = 10^5 \ \textit{radians} \tag{4}$$

The logical qubit has rotated $\sim 10^5/(2\pi) \approx 16{,}000$ full turns from its intended state. The computation is destroyed, and the surface code provided zero protection *because the error was invisible* *to syndrome measurements. This is not a theoretical edge case. Systematic calibration drift is the dominant error source in every superconducting quantum processor ever built. The example above is not a worst-case scenario; it is the default scenario.*

Remark 1. *The billiard-ball analog is immediate: if the table has a systematic tilt, all balls drift in the same direction. Syndrome balls drift with the logical ball, detecting no anomaly. The computation fails silently.*

Proponents may argue that calibration can remove systematic errors. But calibration has finite precision; a residual systematic component always remains. And in a system with 10^6–10^7 physical qubits, calibrating each to 10^{-5} precision relative to all others is itself an unsolved problem.

9 Quantum Error Correction: Detailed Critique

We do not claim that QEC promises "infinite precision." QEC claims error *discretization*: continuous errors are projected onto discrete syndromes. The threshold theorem [20] asserts that if $\varepsilon_{\text{gate}} < \varepsilon_{\text{th}}$, arbitrarily long computation is possible with polynomial overhead.

We identify four specific reasons why the threshold theorem's preconditions are, on current evidence, physically unsatisfiable. No experiment in the 30-year history of the field has demonstrated otherwise:

(1) Threshold boundary. Current best gate fidelities approach $\sim 10^{-3}$, placing them at the optimistic boundary of ε_{th}. The threshold theorem guarantees convergence only for $\varepsilon_{\text{gate}} \ll \varepsilon_{\text{th}}$; at the boundary, the overhead diverges and the recursion may not converge in practice.

(2) Independence assumption. As shown in Example 1, correlated noise defeats syndrome-based detection. Physical systems inherently produce correlated noise through shared environments (Section 8).

(3) Recursive overhead. Each logical qubit requires $\sim 10^3$ physical qubits. The correction circuits require gates that also err. Correcting correction errors requires meta-correction. The recursion converges only if (1) and (2) are strictly satisfied. If either fails, the overhead diverges.

(4) Theoretical objections. Alicki [26] argued that the threshold theorem fails for physically realistic Hamiltonian noise models. Kalai [25] presented mathematical arguments that the structure of realistic noise prevents QEC from working in principle. These objections remain largely unaddressed.

Landauer [31], decades before the current hype, urged researchers to include a disclaimer: "This scheme, like all other schemes for quantum computation, relies on speculative technology, does not in its current form take into account all possible sources of noise, unreliability and manufacturing error, and probably will not work."

10 Formal Framework: Precision Requirements

We now formalize the precision comparison. We emphasize that the following metric is *proposed* as a useful measure of physical realizability, not derived from first principles.

Definition 1 (Continuous-Variable Computational System). *A CVCS is a tuple $\mathcal{S} = (H, D, U, M, \eta)$ where H is a state space with D continuous parameters, $U = \{U_1, \ldots, U_T\}$ is a sequence of T operations, M is a measurement procedure, and η a noise model.*

Definition 2 (Proposed Control Complexity Metric). *The* ***control complexity*** $C(\mathcal{S}) = D \cdot T \cdot \varepsilon^{-1}$, *where D is the effective state space dimension, T the number of operations, and ε the required per-operation precision.*

Remark 2. *The claim that a system requiring control of* 10^{1218} *parameters is harder to build than one requiring* 10^{18} *does not require formal proof. It requires arithmetic. Each factor independently increases difficulty: more parameters to control (D), more operations to perform without error (T), and tighter precision per operation (*ε^{-1}*).*

Table 4: Control complexity for RSA-2048 ($p = 0.99$)

Paradigm	D	C
Billiard balls	$\sim 10^4$	$\sim 10^{18}$
Quantum (logical)	$\sim 10^{1204}$	$\sim 10^{1218}$
Quantum (physical)	$\sim 10^{1807}$	$\sim 10^{1821}$

The quantum computer's control complexity exceeds the billiard-ball computer's by $\sim 10^{1200}$. The quantum system is not merely harder; it is exponentially harder, precisely because the 2^N state space that provides theoretical speedup is the same 2^N state space that makes control physically intractable.

The QEC response. QEC reduces D_{eff} from 2^N to poly(N) under ideal conditions. We do not dispute the mathematics. We dispute the physical realizability of the preconditions (threshold, independence, recursive convergence), as detailed in Section 9. If any precondition fails, D_{eff} reverts to 2^N and the full control complexity resurfaces.

11 The Missing Physics

Locklin [22] offers the analogy: Bernoulli's principle (1738) → SR-71 Blackbird. Between the two lay discoveries unimaginable in 1760: titanium (1791), the petrochemical industry, thermodynamics, electromagnetism, quantum mechanics, information theory. The SR-71 itself was unimaginable.

We identify the analogous "missing physics" for quantum computing:

1. **Materials with coherence** $> 10^6\times$ **current.** Current $T_2 \sim 10^{-6}$ s; useful computation requires ~ 1 s effective coherence (after QEC). No known material or architecture achieves this.
2. **Control of correlated noise.** No method exists to eliminate systematic errors across 10^6–10^7 qubits sharing a common environment. Individual calibration at scale is itself an open problem.
3. **Scalable QEC without recursive divergence.** Current QEC demonstrations involve $\sim$ 10 physical qubits per logical qubit with modest error suppression. Scaling to 10^3 physical per logical, for 10^4 logical qubits, across 10^9 operations, has never been demonstrated or convincingly simulated.
4. **Fundamentally new architecture.** Surface codes require $\sim 10^3$ physical per logical qubit. QLDPC codes promise improvement but require non-local connectivity not achievable on 2D chip architectures. A fundamentally new approach may be needed, one not yet conceived.
5. **Interconnects.** Distributing quantum information across 10^6+ qubits requires quantum interconnects (coherent communication between modules). No scalable quantum interconnect technology exists.

We note that the development of each of these would constitute a major scientific breakthrough, comparable to the discovery of titanium or the formalization of thermodynamics. Expecting all five to occur within a funding cycle is unreasonable. Expecting them within a century has no historical precedent. The history of physics offers no example of five simultaneous fundamental breakthroughs occurring on demand, on schedule, and within budget.

12 Scale of the Engineering Challenge

Table 5: RSA-4096 resource requirements (ranges)

Parameter	Value
Logical qubits	8,195
Physical qubits ($\times 10^3$/logical)	$\sim 8 \times 10^6$
Gates (range: $0.3n^3$ to $72n^3$)	10^{10}–10^{13}
Optical elements ($\sim$3/gate)	10^{10}–10^{13}
Precision per element	10^{-5}
State space (2^{8195})	$\sim 10^{2467}$
Particles in universe	$\sim 10^{80}$
Ratio (state space / universe)	$\sim 10^{2387}$

Without QEC, the probability of error-free completion:

$$P = (1 - 10^{-5})^{5\times 10^{12}} \approx e^{-5\times 10^7} \approx 10^{-21,700,000} \tag{5}$$

Decoherence gap: $T_2 \sim 10^{-6}$ s, computation time $\sim 5 \times 10^3$ s. Ratio: $\sim 10^9$.

13 Comparison with Successfully Scaled Technologies

Neural networks were implemented in hardware in 1958 (Rosenblatt's Perceptron [23]), achieving 99.8% image classification accuracy. Scaling required only more discrete transistors and more data. Blockchain was proposed in 2008 [24] and had a functioning global network within months.

In both cases, the underlying components are *discrete* and require no analog precision. The path from prototype to utility was incremental scaling of robust components. Quantum computing requires scaling *analog* components whose precision requirements increase exponentially with system size.

The key difference: transistors scale because errors are *tolerable* (the signal is binary, noise margin is wide). Qubits do not scale because errors are *catastrophic* (the signal is continuous, noise margin is $\sim 10^{-5}$).

14 Related Work

Skeptics. Dyakonov [11–14] has argued extensively that the quantum computer is fundamentally an analog machine, that continuous-variable control requirements are physically unachievable, and that no continuous quantity can have an exact value. Kalai [25, 38] presented both mathematical arguments against QEC realizability and detailed critiques of Google's supremacy claims. Alicki [26] showed the threshold theorem fails for Hamiltonian noise models. The U.S. National Academies [27] concluded RSA remains safe for decades. Multiple groups [33–36] have empirically demonstrated that classical methods outperform quantum processors on their own flagship benchmarks.

Proponents. Aaronson [28] argued the Extended Church–Turing Thesis is likely false. Preskill [29] introduced NISQ (Noisy Intermediate-Scale Quantum), acknowledging that fault tolerance remains distant. Gottesman [30] developed the stabilizer formalism underlying most QEC codes. IBM [32] and Google [9] have made flagship claims of "quantum utility" and "quantum supremacy" respectively; both have been refuted (Section 3).

Our contribution. We introduce BBEC and CEC as explicit constructions (Section 6) demonstrating that QEC failure modes are not unique to quantum systems, compile the first comprehensive catalog of empirical refutations of flagship quantum claims (Section 3), formalize the precision comparison (Section 10), address the linearity objection via decoherence (Section 7), provide a concrete numerical example of correlated noise defeating QEC (Example 1), and catalog missing physics (Section 11).

15 The Nasreddin Principle

Dyakonov [12] recounts the parable of Nasreddin Hodja, who obtained a ten-year grant from the Sultan to teach his donkey to read. For his first report, he placed breadcrumbs between pages and demonstrated the donkey turning pages with its hooves.

Had he possessed modern sophistication, he could have said: there is no theorem forbidding donkeys to read, and failure would reveal new laws of Nature. A win-win strategy.

The Nasreddin Principle applies equally to quantum, billiard-ball, crab, and protractor computing. In all four cases: (a) no theorem forbids the computation; (b) engineering requirements are astronomically beyond current capabilities; (c) proponents can claim failure would be scientifically interesting.

16 Conclusion

We have shown that quantum computing, billiard-ball computing, crab computing, and protractor computing share a foundational dependence on controlling continuous physical variables with precision that is, by all available evidence, physically unachievable.

Our central contribution, the construction of BBEC and CEC (Section 6), demonstrates that every failure mode making classical analog error correction obviously unworkable has a precise structural analog in quantum error correction. The failure modes are isomorphic (Table 3). The difference between them is not physical but sociological: one set of failures is immediately recognized as fatal, while the other is obscured by abstract formalism.

The burden of proof lies with proponents. After 30 years and billions of dollars, the null hypothesis (that useful quantum computation is physically impossible) has not been rejected by any experimental evidence. The largest number factored is 21. The most celebrated achievement (Google's "supremacy" demonstration) was refuted within three years by classical computers that solved the same problem 10^{10} times faster than Google's original classical estimate [36]. IBM's flagship "quantum utility" claim was reproduced by a single laptop core [34] and, in a fitting coda, by a Commodore 64 [39]. Every flagship quantum claim subjected to rigorous classical comparison has been conclusively outperformed (Section 3, Table 1). The ARDA roadmap's 2012 milestone remains unmet. D-Wave has operated for 25 years without demonstrating quantum speedup. The empirical record is not ambiguous; it is uniformly negative.

We note a revealing asymmetry in the discourse. When skeptics point out that no useful quantum computation has ever been performed, proponents respond that the technology is immature. When skeptics point out that error rates are at the threshold boundary, proponents respond that hardware will improve. When skeptics point out that correlated noise defeats QEC, proponents respond that noise models will be refined. At no point is any falsifiable criterion offered: there is no experimental outcome that proponents would accept as evidence against the feasibility of quantum computing. A theory that cannot be falsified by any experiment is not physics; it is faith.

The gap between quantum computing theory and physical reality is not merely large; it is quantifiably larger (by $\sim 10^{1200}$ in control complexity) than the gaps that have historically separated speculative technologies from working ones. The nanotech revolution of the 2000s, fusion power since the 1970s, and autonomous vehicles since the 2010s all shared the pattern: elegant theory, generous funding, confident predictions, and eventual stagnation when physical reality refused to cooperate.

The classical transistor scales to billions because it is discrete. The qubit does not scale because it is continuous. Thirty years of evidence point overwhelmingly toward this being a fundamental physical boundary, not a temporary engineering limitation. The absence of a formal impossibility proof is not evidence of possibility; it is merely evidence that the problem is difficult to formalize. The absence of a proof that donkeys cannot read is not a grant application.

We close with Landauer's recommended disclaimer [31], which we believe should be mandatory for all quantum computing publications: "This scheme, like all other schemes for quantum computation, relies on speculative technology, does not in its current form take into account all possible sources of noise, unreliability and manufacturing error, and probably will not work."

Until such disclaimers become standard, we recommend equal caution regarding announcements from the quantum computing, crab computing, and billiard-ball computing communities. All three are solving problems on machines that do not exist, using principles that have never been demonstrated at scale, with confidence that is inversely proportional to their experimental achievements.

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