A Falsifiable Resonant-Systems Hypothesis for the Giza Pyramid Complex

Mechanical coupling, architectural specialization, and human-scale vibroacoustics

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Positions marked as granted premises in the text are conditional inputs under examination, not findings.

Abstract

The Giza pyramid complex presents several independently documented features whose physical consequences remain incompletely characterized: a measured dominant structural-response frequency of the Great Pyramid near 2.3 Hz [1]; a systematic increase of relative spectral amplification with elevation, peaking near King's Chamber level [1]; a repeated periodic architectural element (27 paired slots at ~1.7 m spacing) in the Grand Gallery [8]; and disputed remote-sensing claims of deep structures beneath the Pyramid of Khafre [2,3].

This paper develops and attempts to falsify the hypothesis that the Giza pyramid complex functioned as a coupled mechanical-resonant system. It does not claim that this hypothesis has been established. It asks a narrower question: if the disputed subsurface geometry beneath Khafre were independently confirmed, what engineering model would best account for the resulting system, and what observations could falsify that model?

Beginning from a hydraulic-resonator premise, we progressively test and discard several attractive interpretations: a 648 m water-column explanation for the measured 2.3 Hz response (the number is fully accounted for by ordinary structural dynamics); a low-frequency resonant role for the King's Chamber coffer (contact stiffness places its rigid-body modes in the kHz range); position-dependent "sweet spots" within chambers below ~80 Hz (unsupported by any simple bulk standing-wave mechanism); and a single-structure harmonic ladder (excluded by the odd-overtone constraint of fixed-free structures).

Two constrained, falsifiable predictions survive, and neither depends on the disputed subsurface claims: (i) the Grand Gallery's documented ~1.72 m slot periodicity fixes a Bragg-scale acoustic interaction near 99-100 Hz, conditional on substantial periodic elements having occupied the slots; (ii) the Pyramid of Menkaure's substantially smaller height yields a pre-registered geometric-similarity null prediction of 4.6-5.2 Hz for its fundamental, derived from the same first-order scaling that reproduces Khufu's measured value - and a measurement near 2.3 Hz instead would reject that null and demand explanation, with inter-monument coupling one candidate among several (differing effective stiffness, foundation compliance, internal architecture, soil-structure interaction, and mode misidentification being others).

We additionally document that the empirical record on pyramid vibro-acoustics is nearly empty: exactly one peer-reviewed instrumental dataset exists [1]. Every proposed test in this paper is non-invasive, permit-scale, and unrun.

1. Method

1.1 Evidence classes

Claims are divided into six evidentiary classes, marked throughout:

- **OBSERVED**: directly surveyed or instrumentally measured, in citable sources.
- **PUBLISHED MODEL**: derived from explicit numerical or analytical modeling in the literature.

- **OUR CALCULATION**: arithmetic derived here from published geometric or physical parameters.
- **INFERENCE**: an interpretation consistent with observations but not uniquely implied by them.
- **SPECULATION**: a proposed function for which direct evidence is absent.
- **DISPUTED PREMISE**: evidence whose underlying measurement or interpretation is contested.

The purpose of the classification is to prevent engineering plausibility from being presented as archaeological fact.

1.2 Process and prior-art search

The analysis was produced through iterated adversarial review: candidate mechanisms were proposed, then independently stress-tested against published measurements and standard mechanics, with explicit instruction to refute. Prior-art searches (academic indices, preprint servers, independent-researcher repositories, video/podcast transcripts, and forums of the alternative-archaeology community) were run iteratively; twice during drafting they surfaced relevant prior work initially missed (a plateau FEM preprint [18]; the Collins corpus [20]), and the paper's novelty claims were narrowed accordingly. All remaining novelty claims (Section 12) are search-bounded - phrased as "we found no prior publication of" - not absolute.

1.3 Research posture

This work is an independent physics audit, not an archaeological attribution. Competing conventional explanations are retained wherever they remain viable, and several are supported by affirmative evidence noted in place. The purpose is not to establish an alternative history of Giza, but to identify quantitative predictions that allow proposed physical interpretations to be rejected or retained by measurement. The paper examines the hypothesis that Giza functioned as a coupled mechanical-resonant system; it does not present that interpretation as an established archaeological finding. It makes no allegation of suppression, conspiracy, misconduct, or bad faith against Egyptian authorities, archaeologists, universities, journals, or any individual researcher; and no criticism of any party's handling of site access or data. Where conclusions are conditional on the disputed subsurface geometry (Section 2), they fall with it; the SAR-independent predictions (Menkaure's fundamental; the Gallery transfer function) remain testable regardless.

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2. The disputed starting premise

In March 2025, a research group reported satellite-SAR interpretations beneath the Pyramid of Khafre: eight vertical cylindrical structures descending approximately 648 m, surrounded by helical features, connecting to chambers of order 80 m scale [3]. The claims were announced by press conference; no peer-reviewed publication of the Khafre results exists. The group's only peer-reviewed output concerns internal structure of Khufu [2]. Radar specialists state that X-band SAR cannot physically penetrate hundreds of metres of limestone [5]; Egypt's antiquities authority denies that any scan was authorized and rejects the claims [4]. The measured modern unconfined water table lies only ~4-7 m below surface [11]; this neither supports nor excludes deeper confined fluids, but it provides no direct evidence for a ~648 m hydraulic structure.

The deep structures are therefore a **DISPUTED PREMISE**: not independently established by any excavation, borehole, or accepted geophysical method. All conclusions dependent on them are explicitly conditional and are falsified with the premise if the SAR geometry is rejected. Treating the premise as a granted input for stress-testing implies no endorsement of the claim and no criticism of those who dispute it. An independent muography project (ScIDEP) with peer-reviewed instrumentation [15] plans density imaging of Khafre; its eventual deployment will test the premise regardless of the claimants' cooperation.

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3. What direct measurement establishes about Khufu

A 2026 ambient-vibration survey [1] measured 37 locations through the Great Pyramid's chambers, passages, outer blocks and adjacent soil (**OBSERVED**):

- Dominant response at 2.0-2.6 Hz, average ~2.3 Hz, in 76% of structural measurement points. Lower-frequency responses (~1.3-1.4 Hz) were recorded in parts of the lower passage and subterranean system, and some exterior points read below 2.0 Hz - deviations that may themselves carry modal information.
- Adjacent ground fundamental ~0.6 Hz.
- Relative HVSR spectral amplification rising with elevation to ~4 at King's Chamber level (48.7 m), decreasing to ~3 in the relieving chambers above. HVSR amplitude is a horizontal-to-vertical spectral ratio, not an absolute motion transfer function; true chamber amplification would require simultaneous reference-response measurement or operational modal analysis [1].
- Foundation seismic vulnerability index Kg = 8.2 (low).

These observations establish that Khufu behaves dynamically as a coherent masonry structure with a well-defined dominant structural-response frequency (an HVSR peak; not, absent operational modal analysis, an established first eigenmode). They do not establish intentional resonant function. The study's authors interpret the soil-structure frequency mismatch as the mechanism of the monument's seismic longevity and explicitly flag HVSR's inability to resolve full mode shapes, proposing operational modal analysis and finite-element modeling as follow-ups [1].

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4. A failed branch, retained: the 648 m numerical correspondence

Using the free-field sound speed of pure water (1482 m/s at 20 C [9]) as an intentionally idealized model, c/L = 1482/648 = 2.287 Hz, within 1% of Khufu's measured dominant response (**OUR CALCULATION**). This is not a prediction of an actual hydraulic system: confined pressure-wave velocity and modal frequencies depend on conduit-wall compliance, geometry, gas fraction (even tiny entrained-gas fractions can radically reduce wave speed), connectivity, losses and end impedances - none of which are known for the disputed structures. The alleged system is not characterized well enough to be assigned a natural frequency at all, which makes the correspondence weaker than the arithmetic suggests. Three further considerations reduce it to coincidence-grade:

4.1 Mode selection. c/L is not the fundamental of any simple resonator. For a 648 m column it is the second harmonic of the closed-closed configuration (fundamental 1.14 Hz); the physically natural configuration for a shaft opening into a chamber (closed-open) yields 1.72 and 2.86 Hz, missing the measured band by ~25%. A compliant gas termination can relocate modes arbitrarily, but that is an adjustable parameter, not a prediction. Hydrostatic head over 648 m would be approximately 6.4 MPa (64 bar) between top and bottom if the shaft were continuously water-filled, but neither this nor plausible geothermal corrections rescue the frequency correspondence: uncertainties in boundary impedance, wall compliance and gas content dominate the modal prediction. Also:

4.2 The null hypothesis is one line. For a fixed-free shear structure, f1 = Vs/4H. With H = 139-146.6 m (current and original heights) and Vs = 1,000-3,000 m/s (plausible range for jointed limestone masonry), the measured 2.3 Hz requires Vs = 1,279 m/s - an entirely unremarkable value (**OUR CALCULATION**). The quantity being "explained" by a tuned water column is fully accounted for by the pyramid's own height and ordinary stiffness. Two independent systems whose parameter ranges each span a factor of 2-3, landing within 2% of one another, is an expected-coincidence event across a large search space, not evidence of coupling.

4.3 No drive. Sustaining resonance requires narrowband excitation near 2.3 Hz. Ocean microseisms peak at 0.05-0.3 Hz; cultural noise is broadband; geyser-type fill-discharge self-oscillation cycles at periods of seconds to minutes; and water hammer, though capable of strong pressure oscillation, has frequencies set by conduit length, wave speed and boundary conditions rather than any universal value - and requires a triggering change in flow or boundary condition. No identified natural or anthropogenic source at Giza has been shown to supply a persistent narrowband 2.3 Hz drive. By contrast, the measured 2.3 Hz peak requires no external tone at all: broadband ambient noise filtered through the structure's own resonance produces it.

The branch is retained because it demonstrates the paper's method: numerical correspondence alone, with free choice of mode, boundary condition and unverified geometry, is insufficient.

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5. Further failed branches

5.1 The coffer as low-frequency resonator. Stone-on-stone contact stiffness (k of order 10^13-10^14 N/m for the coffer's ~2.2 m^2 footprint) places rigid-body modes of the ~3 t granite box in the tens-of-kHz range; it possesses no resonance in the 1-10 Hz band (**OUR CALCULATION**). Its documented audible ring when struck is plate flexure, computed at ~70-190 Hz for fundamental modes and consistent with folklore reports of 110-160 Hz [12,13]; this is a separate phenomenon with no mechanical connection to the dominant low-frequency structural response. At 2.3 Hz the coffer is an inert coupler riding the floor.

5.2 Within-chamber "sweet spots" below ~80 Hz. At 2.3-9.2 Hz the wavelength in masonry (Vs ~ 1,300 m/s) is 140-565 m against ~10 m chambers; a bulk standing-wave pattern across a chamber cannot exist in this band, and spatial differentiation from wave structure cannot arise until chamber dimension approaches a quarter wavelength, near 80 Hz for granite (**OUR CALCULATION**). This excludes the simple picture of low-frequency nodes and antinodes laid out inside a room. It does not exclude local frequency-dependent response arising from joints, floor and wall compliance, openings, block-scale modes or contact mechanics (cf. Test 5). At the dominant response frequency, elevation remains the dominant position variable, consistent with the measured relative amplification profile [1].

5.3 A single-structure harmonic ladder. In the first-order fixed-free model, overtones occur at odd multiples only: 2.3, 6.9, 11.5 Hz, with no 4.6 Hz member. This is a crude 1D approximation of a 3D masonry body, which may possess bending, torsional or higher-order modes elsewhere in the band; the model's proper use is as a stated prior for Test 4, not as proof that Khufu cannot possess a ~4.6 Hz mode. What the approximation does establish is that a clean even-step "harmonic ladder" is not a generic expectation for a single structure of this type, and any appeal to one requires measured modes, not assumed ones.

5.4 Exotic outputs. Acoustic levitation fails by seven orders of magnitude in radiation pressure and by unfocusable 149 m airborne wavelength; piezoelectric power fails because randomly oriented quartz grains in granite cancel; long-range transmission fails by attenuation scale (of order 100 km, path-dependent). All **OUR CALCULATION**. No claim in this paper involves electrical generation, levitation, or unidentified physics.

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6. From isolated monuments to a coupled site

A physically realistic framework treats the monuments not as isolated tuning forks but as mechanically distinct structures attached to a common substrate: geological excitation, shared bedrock, monument-specific response. Mechanical coupling over ~500 m of competent limestone is physically possible at these frequencies; its magnitude, phase and dominant wave type cannot be inferred without measured site velocities, attenuation/Q structure and a calibrated propagation model, since wave type, layered geology, frequency-dependent Q, scattering and source geometry all enter, and different wave types obey different spreading laws. No specific attenuation figure is asserted here (**INFERENCE**).

A 2025 preprint [18] constructed a three-dimensional finite-element model of the Giza plateau including the pyramids and Sphinx for seismic-vulnerability analysis, computing natural frequencies and dynamic response to seven scaled earthquakes (**PUBLISHED MODEL**, preprint). Because the model necessarily simplifies monument and geological material properties, it demonstrates that coupled-site modeling is feasible **-** not that collective Giza modes have been empirically established. A coupled FEM constrained by measured material properties and the existing HVSR data [1] remains required future work.

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7. Architectural specialization: hypothesis and counter-evidence

The known interiors of the two large pyramids differ substantially (**OBSERVED**): Khafre's passages and chambers concentrate at or below bedrock level [16]; Khufu uniquely contains elevated chambers, the Grand Gallery, paired shaft systems, and a granite chamber complex high in the masonry [8]. If the disputed deep structures beneath Khafre were confirmed, one systems reading assigns roles: Khafre as excitation/geological interface, Khufu as filtering/interaction architecture, Menkaure as secondary coupled element (**INFERENCE**).

The counter-evidence must be stated with equal weight. Petrie documented affirmative physical evidence of a construction-plan revision in Khafre's lower system: the subsidiary chamber's roof cut too deep and plastered over, and a recess consistent with coffin handling; his conclusion was a superseded burial arrangement [16]. Khafre's dual-passage topology is, in plumbing terms, a dip loop that permits but in no way indicates hydraulic function, and a hydraulic reading imports watertight-joint technology unattested at Giza (**OUR CALCULATION / INFERENCE**). Hydraulic/resonant interpretations of Khafre's dual entrance systems are active prior art: Collins treats them explicitly within a coupled-resonator framework [20]. Our contribution here is limited to the null-first evaluation - the plumbing-topology analysis, the Petrie counter-evidence, and the residue test (Test 6) that would discriminate. Menkaure's interior is not a bare "secondary element": it contains the earliest interior decoration in any true pyramid, three granite portcullises, and a chevron granite vault [8], which weakens any tidy role assignment.

The specialization hypothesis is retained only because it is falsifiable: it predicts the three monuments should differ underground in specific ways (Section 11, Tests 6-9), and it dies if equivalent deep infrastructure appears under all three, or none.

A further constraint applies to any machine reading: confirmation of water-filled deep shafts would establish a hydraulic geometry, not a hydraulic machine. A functioning resonant system additionally requires an energy source and a mechanism that converts hydraulic energy into periodic pressure fluctuations capable of coupling to the surrounding structure. A survey of passive hydraulic oscillator classes (ram-type valved cycling, siphon/intermittent-spring oscillation, fluidic and delay-line feedback, vortex shedding, surge-chamber mass oscillation, gas-liquid instability in compliant conduits) identifies none as demonstrably instantiated in verified Giza architecture; that box is deliberately left empty. Two classes could in principle operate at the relevant frequency order - valved ram cycling (typical beat rates of order 0.5-2 Hz) and delay-line feedback, whose frequency is set entirely by feedback-path geometry (**INFERENCE**). If the claimed helical features were confirmed and their connectivity formed feedback paths, a delay-line mechanism would impose a geometry-dependent relationship between path length, effective pressure-wave velocity and oscillation frequency, making spiral length a measurable discriminator. No specific length is preregistered: feedback phase can arise from reflections, compliance and impedance as well as propagation delay, and the effective wave speed in a confined conduit is unknown (**SPECULATION**, conditional on unreleased and disputed data). A water-mass-plus-trapped-gas system is a damped oscillator - it rings when excited but supplies no negative damping, so gas compliance alone cannot sustain oscillation. Ram-pump interpretations of Khufu's lower passages are established prior art: Kunkel's 1959 hydraulic-ram patent and associated "Pharaoh's Pump" thesis [24], Cadman's pulse-generator model, and Hauger's 2025 hydraulic model of the complex [25]. All presently depend on unverified valve or flow-path assignments, and none addresses the deep-source topology considered here. Accordingly, this model treats identification of an appropriate flow instability as a necessary condition, not an inferred component. No driver has presently been identified (Section 4.3).

8. The Grand Gallery as a periodic structure

The Grand Gallery is ~46.7 m long and ~8.6 m high, corbelled in seven steps [8]. Its ramp benches carry 27 regularly spaced pairs of slots, with a further pair at the Great Step (28 total), matched by wall niches.

Slot dimensions: ~14 cm wide, ~18 cm deep, with mean lengths alternating regularly between 52.1 and 59.2 cm - documented by Miatello [19], who attributes the measurements to Petrie (1883, p. 72) and the notch geometry to Maragioglio & Rinaldi (1965) (**OBSERVED**). Axis-to-axis periodicity: 46.7 m / 27 = 1.73 m; an independent modern construction study reports ~1.72 m. The two figures agree within 1%.

For a periodic acoustic array, first-order Bragg interaction occurs at spacing a = lambda/2. With a = 1.72-1.73 m and c = 343 m/s:

$f_B = c / 2a$ = 99.1-99.7 Hz (**OUR CALCULATION**)

No parameter is selected to force the result: the architecture fixes the spacing, air fixes the propagation speed. The ~1.72 m periodicity cannot produce first-order Bragg scattering at 2-11 Hz, where wavelengths (31-171 m) exceed the lattice spacing by a factor of 30-90. Any low-frequency role for the inserts would have to arise through other mechanisms (mass loading, local compliance, damping, side-branch behavior), not through the periodicity itself.

Three qualifications:

1. **Empty vs loaded.** The empty recesses are weak, broadband scatterers. A strong stopband requires substantial periodic elements occupying the slots - elements which, if they existed (timber uprights are independently proposed in conventional scholarship for these sockets), are missing. The measurable prediction for the Gallery as it exists today is therefore a weak periodic signature, not a sharp stopband; the sharp feature is predicted for the reconstructed configuration (Section 11, Tests 1-2).
2. **Bandwidth.** For a sufficiently strong periodic perturbation, the first Bragg interaction is expected near 99-100 Hz. Its bandwidth and attenuation depth cannot be inferred from element count alone: they depend on scatterer strength, impedance contrast, filling fraction, losses and termination conditions, and must be obtained from the dispersion relation or an FEM/BEM model of the actual loaded geometry (Test 2). No quantitative connection from the array to the anecdotal 95-120 Hz chamber band (Section 10.1) is asserted here.
3. **Two-element unit cell.** If the alternating slot lengths reflect alternating insert types, the repeating unit doubles to ~3.4 m and zone-folding introduces additional structure near ~50 Hz (**OUR CALCULATION**, conditional).

Mass loading of 54 inserts at 50-500 kg each is globally negligible (<0.0005% of pyramid mass) but locally non-negligible against the Gallery's own walls (0.6-5.8%), consistent with either an acoustic or a purely structural (tie-beam) function - the static analysis is agnostic (**OUR CALCULATION**).

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9. Human-scale interaction: two regimes and a dose ceiling

Two physically distinct stimulation regimes would coexist in the hypothetical system (**INFERENCE**):

- **~2-9 Hz, structure-borne:** whole-body mechanical response is strongest in the low-single-digit band (seated/standing vertical transmissibility peaks ~4-8 Hz; supine responses in a similar range) [10]. A person mechanically coupled to chamber granite lies within this band's reach. Occupational literature treats prolonged exposure as hazard, not therapy; dose and duration dominate outcomes.

- **~100 Hz, air-and-surface-borne:** cutaneous mechanoreceptors (Pacinian system) respond maximally near 100-300 Hz; the Gallery's Bragg scale (Section 8) falls within this range.

The amplitude question must be stated carefully. Human perception thresholds for whole-body vibration are strongly frequency-, direction-, posture- and duration-dependent; published laboratory thresholds correspond to velocities well below 1 mm/s in parts of the relevant band [10]. Whether the hypothetical system could produce perceptible exposure therefore depends on the measured chamber acceleration spectrum, not on any single threshold number. What the power budget does constrain is strong exposure. A 648 m water column provides ~6.4 MPa of hydrostatic head, but head is not power: continuous hydraulic power P = rho*g*Q*H reaches ~6.4 MW per m^3/s only if a sustained flow traverses the full head, and no inlet, outlet, recharge mechanism or sustained flow rate has been established for the disputed geometry. The deep-water premise therefore supplies a possible pressure reservoir, not an identified power source. A second energy topology should be distinguished from surface-fed head: if the disputed shafts intersected a confined aquifer, artesian pressure could in principle supply hydraulic head directly from below, making controlled discharge - rather than elevated makeup supply - the required surface interface, with trapped atmospheric air as a candidate compliance. The surrounding geology makes the architecture plausible in principle: published hydrogeology immediately northwest of Cairo documents multilayer Tertiary aquifers (Eocene, Oligocene, Miocene) hydraulically connected along normal faults [22]; the plateau itself overlies a fractured carbonate aquifer and forms part of the Abu Rawash structural complex [23]; regional stratigraphy contains deeper permeable sandstone and carbonate units separated by lower-permeability horizons - reservoir/seal architecture capable of confining pressure - and fault-mediated upward communication between aquifer units is documented in Egyptian basins generally [21]. Notably, no known stratigraphic boundary or mapped aquifer coincides with ~648 m beneath Giza: the depth figure has not produced a second coincidence. Known Old Kingdom water infrastructure (the Khufu harbour, the Ahramat Nile branch, Khafre's causeway drainage channel) establishes a gravitationally sensible discharge path. All of this is regional plausibility and topological compatibility, not connectivity: no Giza-specific borehole or hydrostratigraphic dataset establishes a confined aquifer at ~648 m beneath the plateau, and three further conditions become load-bearing under this topology - pressure-retaining boundaries (unattested; note that in saturated formations pore pressure rises with depth, so the differential would concentrate at confining-horizon crossings and engineered interfaces rather than along the full shaft wall), a mechanism converting steady head into periodic oscillation (unidentified), and a demonstrated discharge connection (undemonstrated). If any one fails, this architecture fails. The hypothesis is geological and testable rather than evidentiary. Input power scales with velocity squared, so sustained large amplitudes press against any realistic budget of the granted system (**OUR CALCULATION**). The defensible expectation is modest and potentially perceptible amplitude, not overwhelming somatic drive; in any experiential reading, context (darkness, enclosure, expectation) would carry much of the effect. No claim of therapeutic efficacy, altered-state induction, or biological significance follows from frequency overlap alone (**SPECULATION** boundary explicitly drawn).

A minimal hypothesis requiring no deep infrastructure also exists: wind shear across the exterior shaft openings acting as an edge-tone/Helmholtz source of persistent low-frequency excitation, reported anecdotally in unpublished 1990s measurements [12]. It is testable at zero marginal cost (Section 11, Test 3).

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10. The empirical record

10.1 The instrumental record on Giza vibro-acoustics comprises exactly one peer-reviewed dataset: the 2026 HVSR survey [1]. All other circulating figures are non-reviewed: the 1990s TEF measurements were never released (the well-known "~2.5 Hz" figure was a pre-trip model prediction, not a measurement; the "F-sharp chord" account is secondhand) [12]; the 117 Hz and 438 Hz coffer figures are unpublished, unreplicated, and mutually irreconcilable [13]; a widely quoted 4.47 s reverberation time is untraceable to any measurer or method; and the peer-reviewed 95-120 Hz resonance results routinely cited in support concern Neolithic chambers in Britain and Ireland, not Egypt [7]. No transmissibility comparison (coffer vs floor vs wall) has ever been published. The Grand Gallery has never been acoustically surveyed.

10.2 Water at Giza: measured water table 4-7 m below surface, average ~+15 m elevation, locally 15-15.5 m at Khafre's valley temple (a flagged hazard zone); the Osiris Shaft beneath Khafre's causeway was found flooded at ~25 m depth in 1999 [11,17]. Modern levels are elevated by irrigation and urbanization and are not evidence of ancient conditions. Any water-dependent reading must distinguish four non-interchangeable roles: energy source, transmission medium, mechanical loading, and acoustic coupling layer. At 2.3 Hz a shallow layer is far sub-wavelength and cannot act as a waveguide; at ~100 Hz shallow-water interaction becomes relevant (**OUR CALCULATION**).

11. Experiments capable of falsification

All tests are non-invasive and permit-scale. Predicted values are stated in advance.

Test 1 - Grand Gallery baseline transfer function (1-500 Hz). Swept-sine/impulse response with a microphone array along the Gallery. Prediction for the current empty-socket state: at most a weak, low-Q periodic perturbation near 99-100 Hz; first-order expected axial modes near 3.7 / 7.3 / 11 Hz (+-30%, terminations uncertain). This measurement is the baseline for Test 2, not the discriminator.

Test 2 - Modeled and reconstructed inserts. FEM/BEM model of surveyed Gallery geometry with (a) empty slots, (b) historically plausible timber uprights, (c) alternating A/B elements; optionally a physical scale section. The prediction is conditional and stated so: IF the inserts constitute a sufficiently strong periodic impedance perturbation, the first Bragg feature should center near 99-100 Hz, with bandwidth and attenuation depth to be determined by the model rather than assumed (additional structure near ~50 Hz is possible for the two-element cell). The null model predicts no substantial stopband. Whether historically plausible timber members satisfy the sufficient-scattering condition is precisely what the modeling must determine - the periodicity fixes where Bragg interaction would occur, not that it does. A measured Gallery signature matching the loaded configurations rather than the empty one would indicate the slots once held acoustically significant elements; it would not identify them or their purpose.

Test 3 - Structural-acoustic coherence, wind-conditioned. Simultaneous wall/floor acceleration and air pressure, on calm and windy days. Coherent low-frequency excitation appearing with wind supports the passive edge-tone source [12]; structural-to-acoustic phase coherence at any frequency establishes coupling direction.

Test 4 - Menkaure and Khafre modal surveys. Repeat [1]'s methodology. Pre-registered geometric-similarity null predictions: Khafre 2.2-2.4 Hz (near-twin of Khufu); Menkaure 4.6-5.2 Hz by first-order 1/H scaling. A pyramid is not a uniform fixed-free shear beam - joints, block contacts, internal voids, foundation compliance and 3D modes all enter the effective dynamics, and modal results are known to be sensitive to assumed stiffness - so the null is a similarity baseline, not a structural model. Menkaure near 2.3 Hz despite half the height would reject the similarity null and force investigation of why: candidate explanations include different effective stiffness, foundation compliance, internal architecture, soil-structure interaction, mode misidentification, and inter-monument coupling. Coupling is one candidate, not the default winner - and that is scientifically cleaner than treating the null's failure as uniquely diagnostic. Khufu raw spectra from [1] should additionally be examined for the odd overtones the first-order model predicts (6.9, 11.5 Hz) and for any energy near 4.6 Hz, which that model does not produce; interpretation of a 4.6 Hz feature would require distinguishing higher-order 3D modes of Khufu itself from external forcing before any coupling claim is made.

Test 5 - Coffer/floor/wall transmissibility, 1-250 Hz. Three accelerometers, one session. Pre-registered predictions, split by band: below ~80 Hz, the sub-wavelength chamber geometry predicts no position-dependent field enhancement associated with the coffer's location (Section 5.2). Coffer and floor transmissibility may nevertheless differ through local contact mechanics (seating, friction, rocking, contact stiffness); quantifying any such difference is part of the test, and a difference in this band would reflect contact conditions, not a spatial vibration field. Above ~70-100 Hz, a real difference is permitted and even expected: the coffer's own flexural modes (~70-190 Hz) mean a body in contact with it receives a band-specific structure-borne exposure a body on the floor does not. This cleanly separates the rejected hypothesis (coffer as low-frequency resonator or low-frequency positioning device) from the surviving one (coffer as a higher-frequency structure-borne coupling interface), and its absence below 80 Hz closes a 30-year folklore question.

Test 6 - Khafre lower-passage residue survey. Portable XRF, Raman, RTI/photogrammetry for: horizontal calcite banding, laminated fine sediments, salt-migration gradients, floor-versus-wall differential polish. Presence of a coherent wet-process signature would move the hydraulic reading from **SPECULATION** toward evidence; its absence, given the passages' documented accessibility, would substantially weaken hydraulic interpretations predicting prolonged or repeated wetting of these accessible surfaces - subject to preservation and water-chemistry constraints, since flow regime, duration, later cleaning and subsequent groundwater exposure all affect what survives.

Test 7 - Plateau array. Deploy a synchronized three-component broadband array spanning the three monuments plus off-site reference stations. Estimate cross-spectral coherence, phase velocity, propagation direction and frequency-wavenumber structure, stratified across day/night and wind conditions. A genuine site-scale mode should produce stable spatial eigenstructure not reducible to a persistent external source direction; coherent traveling-wave energy or source-dependent phase patterns would instead support ordinary ambient excitation. Fixed phase relationships alone are insufficient - ambient fields routinely show coherent phase structure from persistent directional sources (traffic, machinery, wind loading, microseisms).

Test 8 - Electroseismic/seismoelectric coherence. Record synchronized seismic and electric-field data and test for reproducible frequency-domain coherence between mechanical motion and electric response. A coherent response whose phase and amplitude vary systematically with inferred saturation would be consistent with electrokinetic coupling; absence of such coherence would weaken, but not by itself falsify, a water-saturated mechanical model. No absolute field amplitude is preregistered: seismoelectric conversion depends strongly on porosity, permeability, electrolyte conductivity, saturation and pore geometry, and field signal-to-noise is notoriously poor; electrodes and magnetometers also see cultural EM noise, telluric variation and electrode polarization unrelated to electrokinetic conversion (**INFERENCE**).

Test 9 - Hydraulic impedance and transient-response characterization (conditional). Prerequisite, requiring no site access: reconstruct lithology, permeability, aquifer confinement and pre-development potentiometric head at 500-800 m beneath Giza from existing petroleum, water-well, seismic and borehole records - i.e., identify the specific formation intersected at the claimed depth, its likely hydraulic properties, and its plausible Old Kingdom potentiometric head relative to the flow circuit's high point and discharge elevation (valley-floor level for a deep-loop topology; plateau-base level if a surface manifold is in the circuit). The criterion is that source head exceed the total hydraulic head required by the flowing circuit - its highest hydraulically connected point plus friction and minor losses - and that sustainable available flow at least match the machine's demand. Head substantially below the circuit requirement kills this variant; storage-limited head would imply an episodic rather than continuous system, which would radically lower the required recharge rate but is presently a possibility, not evidence. If no confined water-bearing unit with significant head exists at the claimed depth, the artesian variant fails without further measurement. Then, if deep fluid-filled structures are independently confirmed and access becomes possible: measure pressure, fluid level, temperature and pressure-wave response to controlled low-energy excitation; determine effective wave velocity, damping, boundary reflection coefficients and modal frequencies directly, rather than inferring them from shaft length. Compare the measured hydraulic transfer function with simultaneous seismic response in the monuments. A reproducible hydraulic mode coherently coupled to a structural mode would constitute the first serious evidence of a coupled hydraulic-mechanical system; its absence would reject the hydraulic-resonator interpretation even if the shafts themselves were real. Confirmed shafts alone establish geometry, not function. If the geometry is confirmed, transient CFD/network modeling should precede any assignment of valves or missing components: the question is whether the measured geometry alone admits a self-excited instability under reconstructed head and flow. If sustained oscillation requires hypothetical components for which there is no physical evidence, the passive-machine interpretation is weakened - the model does not get tuned after seeing the answer.

External to this program, ScIDEP muography [15] will test the deep-structure premise directly upon deployment.

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12. Prior art and bounded novelty

The broad idea families in this paper are old, and we claim none of them. Pyramid-as-resonator, hydraulic-pyramid, and consciousness/acoustics interpretations have decades of proponents (Dunn's coupled-oscillator reading and proposed Gallery resonator elements [12-adjacent literature]; the ram-pump lineage of Kunkel [24], Cadman and Hauger [25]; the vibro-acoustic folklore of Section 10.1). Proposals that the Gallery slots held wooden elements are likewise long-standing in both conventional scholarship (scaffolding/tie-beam readings) and alternative literature (resonator readings).

The closest active prior art is the 2026 corpus of Michael J. Collins [20]. Collins' *Root 5 Anomaly* paper explicitly treats the King's Chamber, the relieving chambers and the Grand Gallery sideramp slots as a coupled system including "a higher-frequency carrier distributed along a half-wavelength slot grid" - priority on the half-wavelength slot-grid interpretation of the Gallery array belongs to Collins. His *Beat Frequency Amplification* paper treats Khafre's dual entrance systems within a hydraulic/resonant mechanism, and his wider corpus (hydraulic impulse harvesting, staged impedance control, granite as pneumatic-mechanical transducer) demonstrates that hydraulic/resonant readings of Khafre and of the Gallery are active, contemporaneous prior art. Our work differs in method, not territory: Collins builds a resonant-engine model; we run an adversarial audit that states conventional nulls first, retains failed branches, and reduces each surviving mechanism to a preregistered discriminating measurement.

The bounded claims that survived our prior-art searches (Section 1.2) are phrased as "we found no prior publication of," never "first ever":

1. The comparison of the disputed ~648 m Khafre geometry with the 2026-measured ~2.3 Hz Khufu response - followed, importantly, by quantitative rejection of that correspondence as evidence (Section 4).
2. The preregistered ~4.6-5.2 Hz Menkaure geometric-similarity null prediction derived from the new Khufu measurement (Test 4).
3. The explicit Bragg-scattering formulation of the Gallery slot array - the quantitative 99-100 Hz prediction from surveyed periodicity and the empty-vs-loaded discriminator experiment (Section 8, Tests 1-2). The underlying half-wavelength observation is Collins' [20]; the claim here is limited to the scattering formulation and the experiment design, subject to continued prior-art qualification.
4. The integrated adversarial, falsifiable systems audit built on the 2026 Khufu dataset: evidence classes, conventional nulls stated first, failed branches retained, and preregistered discriminating tests.

Independent convergence is distinguished from novelty throughout: where others reached adjacent results by different routes (Collins' slot-grid carrier; Danley's low-frequency intuitions; the folklore 95-120 Hz band), we treat that as convergence to be credited, not competition to be dismissed.

13. Reception context and positioning

The nearest precedent for a physics-first hydraulic claim at a pyramid site - the 2024 PLOS ONE model of Djoser's shafts as a hydraulic lift [14] - passed peer review and was then rejected on evidentiary grounds by senior Egyptologists, in part for making archaeological claims without archaeological co-authorship. This paper accordingly makes no archaeological claims: it audits mechanisms, states evidence classes, and proposes instrumentation. Every constructive claim herein is a measurement proposal.

14. Conclusion

This investigation does not demonstrate that Giza was a machine. It demonstrates something narrower: when a disputed premise is provisionally granted and subjected to ordinary mechanics, most of the attractive interpretations fail quantitatively - and what survives is a small set of cheap, sharp, unrun measurements.

The most immediately testable prediction does not depend on the disputed subsurface claims at all: the documented ~1.72 m periodicity of the Grand Gallery's slot array fixes an acoustic interaction scale near 99-100 Hz, conditional on the missing elements having formed a sufficiently strong periodic array. The second does not either: Menkaure's fundamental carries a pre-registered similarity-null prediction of 4.6-5.2 Hz from the same first-order formula that reproduces Khufu's measured 2.3 Hz, and a result near 2.3 Hz instead would reject that null and demand explanation - with coupling among the candidates, not presumed.

Whether either number appears in an instrument is an experimental question. That experiment should precede any claim about purpose. The strangest standing fact of this subject is not any hypothesis: it is that the entire discriminating test program costs less than the documentaries that have been produced about not running it.

Acknowledgments and AI assistance disclosure

AI assistance disclosure: Generative AI systems, including Claude and ChatGPT, were used extensively as research assistants during this investigation - for literature discovery, hypothesis generation, adversarial analysis, calculation checking, prior-art searches, and manuscript development. The author takes responsibility for the paper's claims, calculations, interpretations, and conclusions. Sources supporting load-bearing claims were checked against the underlying publications or primary listings where accessible; a per-reference source-verification ledger is published alongside this document as a supplementary file, with verification gaps recorded explicitly rather than implied closed. Twice during drafting, AI-assisted prior-art search initially missed relevant published work that was later recovered and credited (References 18 and 20); the correction history is preserved in the project's research log.

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Version 1.0, August 2026. The per-reference source-verification ledger is published alongside this document. The internal draft history (v0.1-v0.4) and the round-by-round research log are retained by the author and available on request.