ValerieX (VXXX)

A Symmetry-Based Reorganisation of Classical Buoyancy and Added-Mass Behaviour

Density-State Disequilibrium, Valerie's Law, and the Force of Density

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Reader's Quick-Start

ValerieX does not introduce a new force or contradict classical mechanics. All governing equations are mathematically identical to the established buoyancy and added-mass framework.
What is new is the structural organisation:

- A single bounded contrast variable.
- A unified motion law: $a = g\chi$.
- A clear separation of drive (density contrast), coupling (geometry via C), and resistance (drag).
- A regime-based interpretation of how motion is realised.

The contribution of ValerieX is therefore organisational and interpretive, not a replacement of existing equations.

Abstract

ValerieX (VXXX) is offered as a symmetry-based, motion-first reorganisation of classical buoyancy and added-mass behaviour into a unified framework based on density-state disequilibrium between substance and its surrounding environment. The framework does not deny classical mechanics or Newtonian gravitation, and is fully consistent with the recognised buoyancy-plus-added-mass family of fluid mechanics (Lamb, 1932; Brennen, 1982; Kelvin, 1871). Its contribution is structural: it reorganises the observable behaviours of rest, rise, fall, buoy-

ancy, vacuum free fall, and terminal motion under a single bounded contrast variable, a clean drive/coupling/resistance separation, and a regime-based reading of how the same density-state drive is realised under different pathway conditions.

From this starting point, Valerie's Law is derived as a parameter-free, bounded, antisymmetric, scale-neutral relation between available vertical acceleration and the relative density-state of object and medium. The bounded contrast variable $\chi = (\rho_o - \rho_m) / (\rho_o + \rho_m)$ is shown to be the unique lowest-degree rational form under the four foundational conditions stated in §3; every higher-degree rational solution factors through it. Valerie's Law $a = g\chi$ then follows by minimal sufficiency.

The framework distinguishes available motion (set by χ) from realised motion (set by environmental constraint), and is geometry-aware through the participation coefficient C of the recognised added-mass family. Valerie's Law is recovered exactly at the $C = 1$ branch — the participating-medium-load coefficient for a circular cylinder moving perpendicular to its axis in inviscid potential flow. $C = 1$ is the algebraic branch on which label-exchange antisymmetry holds for the full law; in real systems C remains geometry-dependent across the C-family, with classical values $C = 0.5$ for spheres in inviscid potential flow and $C = 1$ for cylinders perpendicular to their axes recovered within the same framework. The bounded form is therefore a specific member of standard added-mass fluid dynamics rather than an alternative to it.

Realised motion is organised by a regime classification with three operationally distinct regimes — constrained, supported, and unconstrained — each defined by a single directly observable pathway condition. The same χ can express itself as a scale reading, as tension in a support, or as realised acceleration depending on which regime applies. Weight, buoyancy, terminal velocity, and free fall are recovered as expressions of one density-state drive under different regime conditions rather than as separate primitive forces.

Taken together, the bounded contrast χ, the geometry-aware C-family, and the three-regime classification form a single motion-engine identity. ValerieX does not introduce a new measured force in competition with classical mechanics. It identifies a single motion-engine structure beneath the recognised equations: density-state disequilibrium supplies the available drive; geometry determines early-time coupling through C; resistance and drag determine later realised motion; and pathway availability determines whether the same drive appears as acceleration, tension, or weight.

The framework is testable through specific experimental routes that isolate early-time coupling behaviour: an intermediate-density unconstrained measurement at $\rho_o = 2\rho_m$ (where the C-family predicts $a = g/3$ for cylinders ⊥ axis at $C = 1$, $a = 2g/5$ for spheres at $C = 0.5$, and $a = g/2$ for the strict object-normalised $C = 0$ limit which neglects added-mass), and shape-controlled measurements that probe the continuous C-family via paired sphere–capsule–cylinder bodies (sphere $C \approx 0.5$, capsule $0.5 < C < 1$, cylinder ⊥ axis $C \approx 1$). A capsule C(L/D) curve derived from prolate-spheroid added-mass theory converts the geometry test from a binary comparison into a continuous-parameter falsification target. McKee and Czarnecki (2019) provide a positive published anchor for the $C = 0.5$ sphere branch. These tests validate the geometry-dependent coupling structure of classical added-mass theory under the ValerieX organisation; they do not pit ValerieX against classical fluid mechanics, with which the predictions are consistent.

ValerieX is scope-limited to vertical-motion phenomena that can be directly observed, measured, and reproduced under everyday and laboratory conditions. It does not address orbital mechanics, planetary dynamics, or cosmological-scale phenomena, and it does not derive the terrestrial value of g; g is treated as the locally observed environmental ceiling of realised vertical acceleration (NIST CODATA, 2019). Vertical direction within ValerieX is defined locally by the gradient structure of the surrounding medium and is not asserted as a universal cosmological down. The aim of this paper is to invite collaborative engagement with the reorganisation alongside established practice.

This manuscript presents a theoretical and experimental framework; full validation requires new controlled measurements.

Keywords

ValerieX; Valerie's Law; density-state disequilibrium; force of density; bounded contrast; participating medium load; vertical motion; weight; buoyancy; terminal velocity; pathway availability; regime classification; C-family; electromagnetic field; symmetry-based reorganisation; falsifiability.

Note on Volume Structure

This manuscript is the consolidated, read-first paper for the ValerieX framework. Cross-references in the body to Volumes I–IV (cited as Parkyn 2026a–d in the references) appear throughout as V1, V2, V3, and V4 with section numbers, directing readers to supporting technical detail in the four-volume programme: V1 — theory and derivation; V2 — regime classification and experimental discrimination; V3 — computational modelling, discriminators, and figure framework; V4 — experimental protocol and laboratory manual.

Notation

Symbol	Meaning
ρ_o	Density-state of the object (kg m^{-3})
ρ_m	Density-state of surrounding medium (kg m^{-3})
$\Delta\rho$	Density-state difference, $\rho_o - \rho_m$
χ	Bounded density-contrast variable, $-1 < \chi < 1$
r	Density ratio, ρ_o / ρ_m
a	Available vertical acceleration (m s^{-2})
g	Observed environmental acceleration ceiling under full contrast (m s^{-2})
V	Volume (m^3)
C	Participation coefficient of the added-mass family (dimensionless)
R_eff	Effective motion-resistance term (object load + participating medium load)

F_net	Net density-driven force = $Vg(\rho_o - \rho_m)$
v_t	Terminal velocity in a real medium ($m\ s^{-1}$)
β_T	Thermal volumetric expansion coefficient (K^{-1})
η	Dynamic viscosity of the medium (Pa·s)
C_d, A	Drag coefficient (dimensionless); projected area (m^2)

1. Introduction

Bodies in an environment rest, rise, fall, suspend, accelerate, and reach terminal motion in ways that depend on their density relations with their surroundings. Standard teaching distributes the explanation of these behaviours across several constructs: gravity, buoyancy, weight, drag, and resistance. ValerieX asks whether the same range of observations can be organised under one prior question:

Can vertical motion be built from density-state disequilibrium alone?

This paper develops that question into a symmetry-based reorganisation of classical buoyancy and added-mass behaviour. It is fully consistent with the recognised buoyancy-plus-added-mass family of fluid mechanics (Lamb, 1932; Brennen, 1982; Kelvin, 1871) and is not a refutation of Newtonian or relativistic mechanics. The governing equations recover classical results across the C-family. Novelty lies in the structural reorganisation: χ as a bounded organising variable, the drive/coupling/resistance separation, the regime classification, and a unified single-law-plus-pathway-condition reading of the principal observables.

The framing adopted throughout this paper is deliberately twofold. The testable contributions — the symmetry derivation of χ, the regime classification, and the C-family validation programme — are presented first in each section and stand independently of any ontological commitment. The motion-first interpretive reading — density-state disequilibrium as the underlying motion driver, with classical gravity-plus-buoyancy recovered as an effective description that captures the correct observables in terrestrial conditions — is then stated openly. The two coincide numerically across the regimes tested here precisely because the classical net force term $Vg(\rho_o - \rho_m)$ is mathematically identical to the ValerieX drive term. The distinction is structural and interpretive: ValerieX derives the bounded relational law from symmetry principles, supplies a single drive rather than multiple primitive force terms, and introduces an explicit regime classification based on pathway availability. Future work may identify regimes (e.g. extreme density contrasts, non-terrestrial environments, or supported-regime configurations) where the interpretations diverge measurably; the present scope does not depend on any such divergence.

Before the technical build, the engine itself is stated plainly. ValerieX reads vertical motion as a single process with four roles. A drive: density-state disequilibrium between object and surrounding medium, captured by a bounded relational measure χ. A coupling: geometry, expressed through the participation coefficient C of the recognised added-mass family, which sets how the drive translates into early-time acceleration. A resistance: viscous and inertial drag, which sets later realised motion. A pathway condition: whether the surroundings allow the drive to be realised as acceleration, opposed by a support so it appears as tension, or fully blocked so it appears as weight. The remainder of the paper builds these four roles in order and shows that the same single drive accounts for rest, rise, fall, vacuum free fall, weight-response, buoyancy-response, and terminal motion under one law plus medium participation.

The development is anchored in observation throughout. Archimedes (c. 250 BCE) on hydrostatic flotation; Galileo (1638) on the medium-independence of vacuum free fall; Bernoulli (1738) and Euler (1757) on fluid pressure; Stokes (1851) and Reynolds (1883) on viscous and inertial drag; Lamb (1932), Landau and Lifshitz (1959), Batchelor (1967), Schlichting and Gersten (2017), and White (2011) on continuum-mechanical closure; Brennen (1982) and McKee and Czarnecki (2019) on added-mass / participating-medium-load; the NIST CODATA reference for g; Apollo 15 (Scott, 1971) for vacuum free-fall equality; OpenStax, Chladni (1787), Faraday (1831), Helmholtz (1863), Kundt (1866), and Rayleigh (1877) for acoustic phenomena; ACS for thermal density change; and the U.S. Department of Energy and NASA EFM for electromagnetic structuring of substance and atmosphere. The paper does not displace these references; it reorganises the relations between the observables they document.

The paper is organised as follows. Section 2 sets out the ontological starting point of density-state disequilibrium. Section 3 introduces the bounded contrast variable χ and proves its uniqueness. Section 4 derives Valerie's Law and gives the working mathematics. Section 5 develops the interpretation of g as the observed environmental ceiling. Section 6 sets out the geometry-aware C-family extension. Section 7 develops the regime classification of realised motion into constrained, supported, and unconstrained regimes. Section 8 sets out the flagship intermediate-density discriminator at $\rho_o = 2\rho_m$. Section 9 summarises the experimental protocol. Section 10 records scope and limitations. Section 11 concludes.

2. Core Principle: Density-State Disequilibrium

2.1. Primitive Entities

ValerieX begins with three primitives: an object characterised by density-state ρ_o; an environment or medium characterised by density-state ρ_m; and an interaction domain in which both coexist. No primitive upward or downward force is introduced at this stage. Motion is treated as relational, in the spirit of Archimedes (c. 250 BCE) and Galileo (1638).

The framework uses substance rather than matter, volume rather than mass as the primary descriptive basis, and density-state as the primary state variable. These choices are operational, not metaphysical: substance is what physically occupies volume and carries density; volume and density are directly measurable for solids, liquids, and gases (Landau and Lifshitz, 1959; White, 2011). The standard formal definition $\rho = m/V$ is not denied; it is simply not taken as the primary explanatory starting point.

2.2. Disequilibrium as the Source of Motion

The foundational statement of ValerieX is direct:

Vertical motion arises from density-state disequilibrium between substance and its surrounding environment.

Define $\Delta\rho = \rho_o - \rho_m$. The raw difference is unbounded, so the framework requires a bounded relational measure of disequilibrium. That measure is constructed in Section 3.

Equilibrium is defined by $\rho_o = \rho_m$. At this condition there is no vertical motion and no directional preference; rest is state equivalence, not the cancellation of opposing causes. Up and down are not taken as primitive: they emerge from contrast. If $\rho_o > \rho_m$, motion resolves one way; if $\rho_o < \rho_m$, motion resolves the other. These are observable opposite directions of the same process, not two independent force categories. "Down" within ValerieX is therefore a contextual direction — the local resolution direction of denser substance through a less-dense surrounding environment, set by the local gradient structure of the medium, not by any absolute or cosmological reference frame.

2.3. The Force of Density

ValerieX names the physical drive expressed through the framework the force of density — the density-state drive that arises from particle-density contrast within an electromagnetic-field-conditioned environment. It is not a second equation pasted onto the law of Section 4; it is the particle-level meaning of that law. Term for term, $F\_net = Vg(\rho_o - \rho_m)$ is mathematically identical to the classical buoyant net (weight minus Archimedes buoyancy). Within ValerieX this single expression is read as one density-state drive rather than as the sum of two primitive force constructs; the same observable is captured in hydrostatic terms by Archimedes (c. 250 BCE) and organised classically through pressure gradient and buoyancy (Bernoulli, 1738; Euler, 1757; Lamb, 1932). ValerieX identifies it directly at the substance level. The term "force of density" names the same observable captured classically by the buoyant net; it does not introduce an additional measured force, and any force-balance computation using F_net is mathematically interchangeable between the two readings.

2.4. Electromagnetic Field as Structural Condition

Within ValerieX, the electromagnetic field is treated as the foundational structural condition that makes differentiated substance, stable phase states, and meaningful density contrasts possible at all. At the microscopic scale it binds electrons to nuclei, governs chemical bonding, and determines the phase behaviour that gives ordinary matter its characteristic densities (U.S. Department of Energy, The Electromagnetic Force; DOE, Quantum Mechanics; Landau and Lifshitz, 1959). At the macroscopic scale this same field structures the terrestrial environment, enabling the formation of distinct density-states ρ_o and ρ_m.

Direct measurements confirm that the surrounding medium itself carries real electrical structure: NASA electric field mills (EFM) measure the vector components of the atmospheric electric field, revealing electrical gradients even in fair-weather conditions (NASA IMPACT/Earthdata, EFM). ValerieX therefore adopts this established role as foundational: without a field-conditioned environment, the relational density-state variable χ and the resulting disequilibrium that drives vertical motion could not exist.

Importantly, the electromagnetic field is not introduced here as a competing motion force or as the direct cause of vertical acceleration. Density-state disequilibrium within the field-conditioned environment supplies the motion driver, expressed through Valerie's Law $a = g\chi$ and its geometry-aware C-family extension (see §4). Direct electromagnetic interactions govern horizontal behaviours and constraints, while sound and temperature act as environmental modifiers of density-state. This structural distinction is formalised in Axiom 7 and remains fully consistent with the motion-first ontology of the framework.

2.5. Axioms

Axiom	Statement
1. Relational Motion	Motion is defined only relative to an environment.
2. Density-State Sufficiency	Vertical behaviour is determined by the relation between ρ_o and ρ_m.
3. Disequilibrium Drives Motion	Motion occurs only when $\rho_o \neq \rho_m$.
4. Bounded Response	Acceleration must remain finite.
5. Symmetry of Contrast	Positive and negative disequilibrium are opposite branches of the same law.
6. Minimal Sufficiency	No structure is introduced unless required by the axioms.
7. Field-Conditioned Differentiation	Differentiated substance and stable density-states are possible because substance exists within a field-conditioned environment.

3. The Bounded Contrast Variable χ

3.1. Problem Statement

Given the axioms, the task is to determine the relation governing vertical motion in an observable environment. We seek a function $\chi = f(\rho_o, \rho_m)$ measuring density-state disequilibrium in a bounded, symmetric way. It must satisfy four conditions:

- Equilibrium: $f(\rho_o, \rho_m) = 0$ whenever $\rho_o = \rho_m$.
- Antisymmetry: $f(\rho_o, \rho_m) = -f(\rho_m, \rho_o)$.
- Scale-neutrality (homogeneous of degree 0): $f(\lambda\rho_o, \lambda\rho_m) = f(\rho_o, \rho_m)$ for any $\lambda > 0$.
- Bounded response: $|f(\rho_o, \rho_m)| < 1$ for all $\rho_o, \rho_m > 0$.

The unique lowest-degree rational form satisfying these four conditions simultaneously, under the standing assumption that χ is a rational function of (ρ_o, ρ_m), is

$\chi = (\rho_o - \rho_m) / (\rho_o + \rho_m)$.

The remainder of this section establishes the result in three steps: direct algebraic verification, the lowest-degree minimality argument, and the full characterisation across higher degrees. This form is also recognised in classical fluid mechanics as the Atwood number, which appears naturally in buoyancy-driven flows; ValerieX adopts it as the bounded organising variable of the framework and derives it from the four foundational conditions above.

3.2. Algebraic Verification

Let $\rho_o, \rho_m > 0$. Equilibrium: if $\rho_o = \rho_m$, the numerator vanishes and $\chi = 0$. Antisymmetry: $\chi(\rho_m, \rho_o) = (\rho_m - \rho_o)/(\rho_m + \rho_o) = -\chi(\rho_o, \rho_m)$. Scale-neutrality: $\chi(\lambda\rho_o, \lambda\rho_m) = \lambda(\rho_o - \rho_m)/[\lambda(\rho_o + \rho_m)] = \chi(\rho_o, \rho_m)$. Boundedness: by the strict triangle inequality $|\rho_o - \rho_m| < \rho_o + \rho_m$, so $|\chi| < 1$, with equality approached only in the singular vacuum limits $\rho_m \to 0$ ($\chi \to +1$) and $\rho_o \to 0$ ($\chi \to -1$). All four conditions are satisfied exactly.

3.3. Minimality at Lowest Degree

Step 1. Scale-neutrality forces a homogeneous-of-degree-0 ratio. Any rational function representing χ can be written as $P(\rho_o, \rho_m)/Q(\rho_o, \rho_m)$, where P and Q are homogeneous polynomials of equal degree d (otherwise the ratio scales as a non-zero power of λ).

Step 2. Antisymmetry forces parities: P must be odd under the swap ($P(\rho_m, \rho_o) = -P(\rho_o, \rho_m)$) and Q even ($Q(\rho_m, \rho_o) = Q(\rho_o, \rho_m)$).

Step 3. At lowest degree $d = 1$: the only odd linear form (up to scaling) is $a(\rho_o - \rho_m)$; the only even linear form is $b(\rho_o + \rho_m)$. Therefore the most general lowest-degree solution to the first three conditions is $f = k(\rho_o - \rho_m)/(\rho_o + \rho_m)$, with $k = a/b \neq 0$.

Step 4. Boundedness fixes $|k| \leq 1$, and equality is achieved at the vacuum limits for $k = \pm 1$; the conventional positive sign under positive disequilibrium fixes $k = +1$.

The unique lowest-degree rational function satisfying all four conditions is therefore $\chi = (\rho_o - \rho_m)/(\rho_o + \rho_m)$.

3.4. Higher-Degree Characterisation

It is natural to ask whether higher-degree rational functions can also satisfy the four conditions. They can — but every such solution factors through χ multiplied by an even, scale-neutral correction.

By Steps 1–2 above, any solution can be written as P/Q with P odd and Q even of equal degree d. Because P is odd and vanishes on the diagonal $\rho_o = \rho_m$, it admits the unique factorisation $P = (\rho_o - \rho_m) \cdot E_1$, where E_1 is homogeneous of degree $d - 1$ and even under the swap. The denominator Q is already even and homogeneous of degree d. Substituting,

$$f = \chi \cdot [(\rho_o + \rho_m) \cdot E_1 / Q] = \chi \cdot R,$$

where R is even and scale-neutral. This is the General Theorem: every rational solution of the four conditions has the form $f = \chi \cdot R$ for some even, scale-neutral rational R. At $d = 1$, R reduces to a constant fixed by boundedness, and the basic χ is recovered. At higher d, non-trivial R produces solutions such as $\chi^3 = \chi \cdot \chi^2$ (with $R = \chi^2$) and other odd-power or composite combinations. These exist algebraically but introduce structure not required by the axioms. By Axiom 6 (minimal sufficiency), ValerieX selects the lowest-degree form: the unadorned χ.

3.5. Properties of χ

For positive density-states, $-1 < \chi < 1$. Special cases: $\chi = 0$ if $\rho_o = \rho_m$; $\chi \to +1$ if ρ_o □ ρ_m; $\chi \to -1$ if ρ_o □ ρ_m. The variable encodes both direction and degree of disequilibrium in one bounded number.

4. Valerie's Law: a = gχ

4.1. Derivation

By Axiom 3, motion follows disequilibrium. By Axiom 4, motion remains finite. By Axiom 5, opposite contrasts are opposite branches of the same law. The simplest governing relation is linear proportionality between available vertical acceleration and bounded contrast: a □ χ. Introducing the observed environmental scale g gives Valerie's Law:

$$a = g \cdot (\rho_o - \rho_m) / (\rho_o + \rho_m) = g\chi.$$

This is the governing law of available vertical motion within ValerieX. It is parameter-free, bounded, antisymmetric, scale-neutral, and continuous. The framework distinguishes available motion (set by χ) from realised motion (set by environmental constraint); Section 7 develops that distinction through the regime classification.

4.2. Independent Derivation from Participating Medium Load

Valerie's Law also arises from a direct dynamics argument when the effective inertia of the object–environment system is written correctly. The net density-driven force on an object of volume V is

$$F\_net = V\, g\, (\rho_o - \rho_m).$$

In classical terminology, the medium's inertial participation is described as added mass or virtual mass. ValerieX retains the observable effect but reframes its meaning: it is participating medium load, the measurable extent to which surrounding substance must be co-disturbed when disequilibrium resolves (McKee and Czarnecki, 2019; Lamb, 1932). The effective motion-resistance term is

$$R\_eff = (\rho_o + C\rho_m)\, V,$$

where C is the participation coefficient. The available acceleration is

$$a = F\_net / R\_eff = g \cdot (\rho_o - \rho_m) / (\rho_o + C\rho_m).$$

Brennen (1982) tabulates classical potential-flow added-mass coefficients: 0.5 for a sphere and 1.0 for a circular cylinder moving perpendicular to its axis. Valerie's bounded form is recovered exactly at C = 1: the participating-medium-load coefficient for a circular cylinder moving perpendicular to its axis in inviscid potential flow. The bounded form is therefore not a free ansatz; it is an exact branch of a recognised geometry-dependent family. Interpretively, what classical fluid mechanics calls "mass" in this context is read in ValerieX as participation of the medium in realised motion, not as a foundational cause. This independent mechanistic recovery of the C = 1 branch corresponds to the form fixed in §3 by the four foundational conditions: the symmetry argument and the participating-medium-load argument converge on the same bounded relation.

4.3. Working Formulas

4.3.1. Core Law and General Form

Bounded core law:

$$a = g \cdot (\rho_o - \rho_m) / (\rho_o + \rho_m) = g\chi.$$

Geometry-aware general law:

$$a = g \cdot (\rho_o - \rho_m) / (\rho_o + C\rho_m).$$

Net force, effective resistance, and acceleration:

$$F\_net = V\, g\, (\rho_o - \rho_m),\ R\_eff = (\rho_o + C\rho_m)\, V,\ a = F\_net / R\_eff.$$

4.3.2. Limiting Regimes

Regime	Condition	Consequence
Equilibrium	$\rho_o = \rho_m$	$\chi = 0$, $a = 0$ (rest)
Positive disequilibrium	$\rho_o > \rho_m$	$\chi > 0$, $a > 0$ (denser falls)
Negative disequilibrium	$\rho_o < \rho_m$	$\chi < 0$, $a < 0$ (lighter rises)
Full positive saturation	ρ_o □ ρ_m	$\chi \to +1$, $a \to +g$ (vacuum-limit fall)
Full negative saturation	ρ_o □ ρ_m	$\chi \to -1$, $a \to -g$ (max-contrast rise)
Near-equilibrium (linear)	$\rho_o = \rho_m + \varepsilon$	$\chi \approx \varepsilon/(2\rho_m)$, $a \approx g\varepsilon/(2\rho_m)$
Antisymmetry swap	$o \leftrightarrow m$	$a(\rho_o, \rho_m) = -a(\rho_m, \rho_o)$

4.3.3. Realised Motion and Terminal Velocity

Valerie's Law gives available acceleration. Realised motion is the constrained expression of available motion, mediated by drag in real media. For a low-Reynolds sphere (Stokes, 1851):

$$v\_t = F\_net / (6\pi\eta r).$$

For a general bluff-body regime:

$$v\_t = \sqrt{[\, 2 \cdot |\Delta\rho| \cdot g \cdot V / (C\_d \cdot \rho_m \cdot A)\,]}.$$

Both are dissipative completions of the picture: density-state disequilibrium sets the drive; the medium sets the constraint; terminal velocity is the realised steady state. These results compose directly with Valerie's Law without changing its foundation (Stokes, 1851; Reynolds, 1883; Batchelor, 1967; Schlichting and Gersten, 2017; White, 2011). The full transient ODE that interpolates between the early-time C-family acceleration and the drag-limited terminal velocity is given in V3 §8.3 and V4 §11; both reduce identically to the C-family acceleration at $v = 0$.

4.3.4. Temperature, Pressure, and Sound as Density-State Modulators

For substances with thermal expansion coefficient β_T, $\rho(T) = \rho_0 / [1 + \beta_T (T - T_0)]$; for gaseous media, $\rho = pM/(RT)$. Both relations enter Valerie's Law directly through ρ_m (and through ρ_o where the object contains a compressible substance). Heating reduces ρ; cooling raises it; pressure modifies trapped-gas density via Boyle's Law (Boyle, 1662). These chains govern hot-air balloon rise, convection cells, lava-lamp motion, and Cartesian-diver behaviour (ACS, Temperature Affects Density). Sound enters Valerie's Law as a time-varying ρ_m, with the pressure wave perturbing the local medium density around its baseline. Resonance occurs where a structure's natural mode matches the forcing frequency (OpenStax; Rayleigh, 1877). Acoustic levitation and Chladni patterns (Chladni, 1787; Faraday, 1831; Kundt, 1866) are consequences: particles collect at pressure nodes where the local time-averaged contrast is minimal.

4.3.5. Worked Examples

Scenario	**ρ_o (kg/m³)**	**ρ_m (kg/m³)**	**χ**	**a = gχ (m/s²)**	**Direction**
Lead ball in air	11340	1.225	+0.99978	+9.805	falls
Volleyball in air	80	1.225	+0.9699	+9.511	falls
Iron anvil in mercury	7870	13534	−0.2647	−2.596	floats high
Ice in water	917	1000	−0.0433	−0.425	floats low
Volleyball in water	80	1000	−0.8519	−8.353	rises fast
Helium balloon in air	0.179	1.225	−0.7451	−7.305	rises
Hot-air balloon (~100 °C)	0.95	1.225	−0.1264	−1.239	rises gently
Air bubble in water	1.225	1000	−0.99756	−9.783	rises maximally
Rock in water	2700	1000	+0.4595	+4.505	sinks
Vacuum (ideal)	any > 0	0	+1.0000	+9.807	universal fall

All cases are described by the same bounded relation $a = g\chi$. Every example sits somewhere on the same curve.

5. Interpretation of g as the Observed Environmental Ceiling

Within ValerieX, g is taken as a primitive observed environmental quantity rather than as a derived one. It is the maximum realised vertical particle acceleration available in the local environment under full contrast. NIST gives the standard acceleration of gravity as exactly 9.80665 m s^{-2} (NIST CODATA). ValerieX treats that near-surface terrestrial value as the observed ceiling. Classical mechanics derives the local value of g from Newtonian gravitation as $g = GM_E/r^2$ together with Earth's mass, radius, and rotational/oblateness corrections, and predicts its variation with altitude, latitude, and planetary body. ValerieX makes no equivalent derivation; this represents a scope boundary relative to the classical gravitational derivation and is stated as such. Within the present scope of terrestrial vertical motion, g enters the framework as an observed environmental ceiling and its near-surface value is taken from measurement.

The vacuum case is where the ceiling is most cleanly revealed: as $\rho_m \to 0$, every positive-density object enters the same maximum contrast condition, so all bodies share the same realised acceleration. Substituting $\rho_m \to 0$ into Valerie's Law gives a = g for any positive ρ_o. In the vacuum limit, the ratio $\rho_o / \rho_m \to \infty$, so all positive-density objects are infinitely denser than the surrounding medium in the limiting ratio sense and therefore occupy the same maximum-contrast state with $\chi \to 1$. This does not imply infinite object density. Universal free-fall equality follows directly. This is the observable demonstrated on the lunar surface during Apollo 15 (Scott, 1971), in line with Galileo (1638). More generally, in the vacuum limit the participating medium load $C\rho_m$ vanishes for any value of C; the geometry-aware general law collapses to a = g for every C-branch simultaneously, and the medium's viscous resistance also vanishes. Geometry, coupling, and drag have no effect on realised acceleration in this limit.

5.1. g as a Pathway-Availability Ceiling

Within ValerieX, the terrestrial acceleration scale g = 9.80665 m s^{-2} (NIST CODATA) is interpreted as the local environmental ceiling of realised vertical acceleration. This value is not treated as the cause of motion itself, but as the maximum realised acceleration permitted when pathway availability is effectively complete. When the downward pathway is fully available, density-state disequilibrium is expressed directly as motion, approaching this environmental ceiling. When pathway availability is reduced or blocked, the same underlying motion tendency is instead expressed as constrained interaction (weight) or balanced by the surrounding environment. This pathway-availability reading provides the link between the scalar law $a = g\chi$ and the regime classification developed in Section 7.

The framework makes no claim to derive g from first principles, and it does not propose a mechanism for the terrestrial acceleration ceiling beyond its status as a measured environmental quantity. Any extension of ValerieX into non-terrestrial environments would require independent measurement of the local ceiling and is outside the scope of the present formulation.

5.2. Vacuum Collapse of Geometry and Resistance

The vacuum limit gives a direct structural reading of the motion engine. Substituting $\rho_m \to 0$ into the geometry-aware general law,

$$a \to g \cdot (\rho_o - 0) / (\rho_o + C \cdot 0) = g,$$

for every positive ρ_o and every finite C. The participating medium load $C\rho_m$ vanishes, and the medium's viscous resistance vanishes simultaneously. Geometry, coupling, viscosity, drag, and medium participation all collapse out together.

ValerieX reads vacuum universality directly as the saturation limit of density-state contrast. All positive-density objects occupy the same maximum contrast state relative to a zero-density medium ($\chi \to +1$), so all bodies share the same realised acceleration. The Apollo 15 hammer-and-feather demonstration (Scott, 1971) is the visible signature of this collapse. This is a structural derivation of why geometry, viscosity, and density differences cease to matter once the medium term vanishes; it is not a first-principles derivation of terrestrial g, which remains a measured environmental quantity throughout the framework.

6. The C-Family: Geometry-Aware Extension

6.1. The C-Family of Acceleration Laws

In real media the surrounding substance does not participate uniformly. The realised acceleration depends on the geometric manner in which the object disturbs and is dynamically coupled to the medium. The geometry-aware general law is therefore

$a = g \cdot (\rho_o - \rho_m) / (\rho_o + C\rho_m)$,

with the following recognised values (Brennen, 1982; Lamb, 1932; Kelvin, 1871):

- $C \to 0$: negligible medium participation (vacuum limit or strict object-normalised form);
- $C = 0.5$: spherical objects in inviscid potential flow;
- $C = 1$: cylinders moving perpendicular to their axes (the ValerieX bounded branch).

Valerie's Law is recovered identically at $C = 1$. C is not a universal constant: in real systems it is set by geometry and medium interaction, with the classical values recovered within the same framework. The $C = 0.5$ sphere branch and $C \to 0$ strict object-normalised branch retain their classical scope and provide the basis for the shape-controlled measurements proposed in Section 9.

6.2. The C = 1 Branch within the Family

The four foundational conditions of §3 apply to the acceleration law as a whole, not only to the bounded contrast variable χ. Equilibrium and scale-neutrality are satisfied throughout the family. Antisymmetry under exchange of density labels $\rho_o \leftrightarrow \rho_m$, however, places a non-trivial constraint on the denominator. Direct exchange of densities gives

$a(\rho_o, \rho_m) = -a(\rho_m, \rho_o) \Leftrightarrow \rho_o + C\rho_m = \rho_m + C\rho_o$,

which simplifies to $(1 - C)(\rho_o - \rho_m) = 0$ and so requires $C = 1$ for all $\rho_o \neq \rho_m$. Boundedness then follows automatically: at $C = 1$ the strict triangle inequality $|\rho_o - \rho_m| < \rho_o + \rho_m$ gives $|a/g| < 1$, with equality approached only in the singular vacuum limits.

This is a label-exchange algebraic property of the C-family, not a physical privileging of any particular configuration. $C = 1$ is the algebraic branch on which label-exchange antisymmetry holds for the full law; in real systems C remains geometry-dependent across the C-family. The $C = 1$ branch is the bounded member of the family on which Valerie's Law is recovered, and it coincides classically with the cylinder ⊥ axis added-mass coefficient (Kelvin, 1871; Lamb, 1932; Brennen, 1982). The $C = 0.5$ sphere branch and $C \to 0$ strict object-normalised branch retain their classical scope, and C in any given configuration is determined by geometry and medium interaction rather than by an algebraic preference.

6.3. Geometry as a Discriminator

The geometry-aware extension admits a direct empirical reading. Geometry controls how an object couples to its surrounding medium: it determines how much of the medium is co-disturbed when motion is realised, and therefore which member of the C-family describes the early-time acceleration. In the vacuum limit ($\rho_m \to 0$) every C-branch collapses to the same value a = g, and geometry plays no role; this is the regime in which the Apollo 15 hammer-and-feather demonstration (Scott, 1971) is exact. At finite ρ_m, the amount of participating medium load depends on shape, orientation, and surface interaction with the surrounding substance (Brennen, 1982; Lamb, 1932).

Within ValerieX, this gives a sharp discriminator: spheres minimise orientation effects and are predicted to track the inviscid-sphere branch (C = 0.5); cylinders moving perpendicular to their axes are predicted to track the C = 1 branch. Other geometries (cubes, hemispherical-ended capsules, irregular bodies) introduce orientation-dependent coupling whose realised acceleration sits between these branches and varies with attitude. The shape-controlled measurement programme of Section 9 follows directly from this structure.

Geometry shapes the realisation of density-state disequilibrium by controlling how the object displaces, disturbs, and couples to the surrounding medium.

Geometry does not generate motion. Density-state contrast is the engine of motion. Geometry controls how the object couples to the surrounding medium once motion is expressed: at the instant of release, this coupling appears through C; as velocity develops, the same coupling composes with the medium's viscous and inertial resistance to produce drag. Depending on shape, orientation, and surface interaction, geometry can either reduce or increase this resistance.

6.4. The Capsule Continuous Discriminator

A central computational result developed in V3 §6 is the prediction for the capsule (hemisphere-ended cylinder) participation coefficient as a function of cylindrical-section aspect ratio L/D, computed from the closed-form added-mass coefficient for a prolate spheroid in motion perpendicular to its long axis (Lamb, 1932 §126; Brennen, 1982 Table 1). For a prolate spheroid with semi-major axis a and semi-minor axis b, motion perpendicular to the long axis gives an added-mass coefficient $k_\perp = \beta_0 / (2 - \beta_0)$, where $\beta_0 = 1/e^2 - [(1 - e^2)/(2e^3)] \cdot \ln[(1 + e)/(1 - e)]$ and $e = \sqrt{(1 - (b/a)^2)}$ is the spheroid eccentricity. For a capsule of cylindrical-section length L and end-cap diameter D, the body is mapped to an equivalent prolate spheroid of aspect ratio a/b = (L/D) + 1, which matches both limits exactly: at L/D = 0 the capsule is a sphere (a/b = 1, $k_\perp = 0.5$); as $L/D \to \infty$ the capsule approaches an infinite cylinder ($a/b \to \infty$, $k_\perp \to 1$). $C = k_\perp$ in our notation.

L/D	Spheroid a/b	Predicted C	a/g at r = 2	a at r = 2 (m s^{-2})
0.0	1.00	0.500	0.4000	3.923
0.5	1.50	0.580	0.3949	3.872
1.0	2.00	0.704	0.3698	3.626
1.5	2.50	0.781	0.3601	3.531

2.0	3.00	0.804	0.3566	3.498
3.0	4.00	0.864	0.3494	3.426
4.0	5.00	0.890	0.3461	3.394
6.0	7.00	0.929	0.3414	3.348
8.0	9.00	0.954	0.3386	3.320

The curve passes exactly through the sphere limit C = 0.5 at L/D = 0 and approaches the cylinder ⊥ axis limit C = 1 monotonically as L/D grows. This converts the capsule shape-controlled experiment from a binary sphere-vs-cylinder discriminator into a continuous-parameter falsification test: any monotonic L/D trend in measured early-time acceleration that does not track this curve would directly challenge the prolate-spheroid mapping or the C-family structure. The mapping a/b = (L/D) + 1 is a first-order approximation; CFD or boundary-element calculation can produce a more accurate curve if needed. The ordering predicted here — a_sphere(r) > a_capsule(r) > a_cylinder(r) at fixed r > 1, monotonic in L/D — is the structural prediction of the framework and does not depend sensitively on the spheroid mapping. (V3 §6 plots the corresponding Figure 4.)

7. Regimes: Constrained, Supported, Unconstrained

7.1. Why Regime Classification Is Required

ValerieX distinguishes available motion (set by χ) from realised motion (set by environmental constraint). That alone forces classification. Valerie's Law gives one number — available acceleration a = gχ — for any pair (ρ_o, ρ_m). But the realised behaviour at the same (ρ_o, ρ_m) is not one number. A lead ball at rest on a table, hanging from a wire, and in free fall all share the same χ. They differ in how the available motion is expressed. That difference is not described by χ; it is described by the environment's relationship to the downward pathway.

A regime is determined by pathway availability. Whether downward motion is blocked, held, or free determines how the same density-state drive is expressed. The regime is read directly from the configuration. The classification adds no new physical content to the framework; it names and organises the realised-motion structure that the available/realised distinction already establishes.

7.2. The Three Regimes

Constrained Motion The downward pathway is physically blocked by a rigid surface beneath the object. Motion is prevented. Density-state disequilibrium cannot resolve through displacement and is instead expressed as a sustained, measurable contact interaction at the point of support. Weight is the realised expression of constrained vertical motion under blocked pathway availability. The constrained regime is the regime in which weight is realised. A weighing scale is a constrained-regime instrument; its reading is the force-response at the point of support produced by the environment's blocking of the otherwise-available resolution of χ. Operational signature: a rigid surface is present beneath the object, the object is in contact with it, and the surface prevents further vertical resolution. All surface-supported rest states fall in this regime.

Supported Motion The object is held from above by a string, wire, cable, fibre, or other tension element, while the downward pathway beneath the object remains physically open. No rigid surface blocks descent. Motion is not realised, but the non-realisation is accomplished by tensile support from above, not by obstruction from below. This regime is structurally distinct from the constrained regime even though both share the observation of zero realised motion. In the constrained regime motion is blocked; in the supported regime motion is held. ValerieX identifies the measured tension in the supporting element as the transmitted force of density: the unresolved drive of non-realised motion, transmitted through the supporting element rather than through a blocking surface. Operational signature: a tension element bears the object from above, and there is visible clearance — air, fluid, or vacuum — beneath it. A chandelier on a hook, a plumb bob, a mass on a spring scale, and a Cavendish-balance test mass all operate in this regime.

Unconstrained Motion The downward pathway is fully open and no external element holds the object. Density-state disequilibrium resolves through motion itself. Available motion is realised to the extent that the medium permits; in vacuum, available and realised motion coincide and the object accelerates at the environmental ceiling g. This is the regime in which Valerie's Law operates in its most directly expressive form. No interpretive layer sits between the density-state drive and the observed motion. The Apollo 15 hammer-and-feather demonstration (Scott, 1971) is the canonical visual anchor: $\rho_m \to 0$ collapses every positive-density object onto the same $\chi \to +1$ and the resulting realised acceleration is g for all. The unconstrained regime also covers everyday cases in air where drag partially constrains the pathway. Valerie's Law still supplies the available drive, and the realised motion is its expression under the available pathway conditions. Terminal velocity is the realised steady-state outcome of progressive pathway constraint; the regime remains unconstrained in the structural sense that no blocking surface or tensile support is present.

7.3. The Operational Criterion

The classification of any system is determined by a single observable condition:

Is the downward pathway physically blocked by a rigid surface beneath the object, held by a tensile element from above, or fully open?

7.4. Regime Summary

Regime	Pathway condition	Realised outcome	ValerieX reading
Constrained	Blocked by rigid surface	Motion prevented; force at contact	Weight realised

Supported	Held from above; clear beneath	Motion not realised; tension in support	Force of density transmitted; weight not realised
Unconstrained	Fully open beneath	Motion realised; $a \to g\chi$, bounded by medium	Valerie's Law expressed directly

7.5. The Same χ in Different Regimes

The same χ can appear in all three regimes, and the regime — not χ alone — determines the measurable signature. The brick-on-table, brick-hung, brick-dropped triplet shares identical $\chi \approx +0.999$ against air; what differs is how that χ-drive is environmentally expressed. The regime classification therefore replaces force-first vocabulary, where the same object is said to experience different forces in different contexts (gravity and buoyancy, gravity and drag, gravity and normal force, and so on), with a unified reading: the object experiences one density-state drive, and the environment expresses it in one of three regimes. There is no need to multiply forces to match the observations.

Scenario	**ρ_o (kg/m³)**	**ρ_m (kg/m³)**	**χ**	**Regime**
Brick on table, air	~1800	1.225	+0.9986	Constrained
Brick hung from string, air	~1800	1.225	+0.9986	Supported
Brick dropped in air	~1800	1.225	+0.9986	Unconstrained
Iron anvil in mercury	7870	13534	−0.2647	Unconstrained (buoyant)
Volleyball held under water	80	1000	−0.8519	Unconstrained (buoyant)
Air bubble in water	1.225	1000	−0.9976	Unconstrained (buoyant)
Cavendish test mass, air	~11340	1.225	+0.99978	Supported
Apollo 15 hammer, lunar vacuum	~2700	$\to 0$	$\to +1$	Unconstrained (vacuum)
Helium balloon, air	0.179	1.225	−0.7451	Unconstrained (rising)

The first three rows make the point vividly. The same brick has the same χ in all three regimes. The signature it leaves in the world — scale reading, string tension, or realised fall — is completely different. The regime is where the difference lives; χ is where the drive lives.

7.6. Pathway Availability and the Realisation of Weight

Within ValerieX, weight is not treated as a continuously expressed property, but as a realised condition arising from environmental constraint. Weight does not appear or disappear; it is either realised or unrealised depending on pathway availability. The unified statement is direct:

Density contrast defines the available motion tendency. Pathway availability deter-

> *mines whether that tendency is realised as motion, tension, or weight. Surrounding-environment displacement determines equilibrium.*

Equilibrium under ValerieX is not the absence of disequilibrium but its balanced expression against the surrounding environment. When the local environment fully displaces the downward motion tendency — as for a body suspended in a fluid at the layer where ρ_o = ρ_local — χ vanishes and no realised motion follows. Density-column stratification, Cartesian diver behaviour, and floating bodies in liquids are all recovered as expressions of this principle.

7.7. Same Drive, Different Realised Signature

Classical language describes the same object differently depending on context: weight on a table, tension on a string, acceleration in free fall, buoyant response in a fluid. ValerieX claims that the cleaner invariant is the bounded contrast variable χ. The same χ can appear as a scale reading in the constrained regime, as tension in the supported regime, or as acceleration in the unconstrained regime.

The motion-engine prediction is therefore organisational rather than purely numerical:

> ***The measured quantity changes because pathway availability changes, not because the density-state drive changes.***

ValerieX accordingly predicts that regime transition experiments should preserve the same underlying density-state drive while changing only the realised channel of expression. A drop-box scale reading going to near zero during free fall (Experiment 3, §9.4) is not interpreted as the disappearance of the drive, but as the removal of the constrained-regime pathway that realises weight. The χ-drive itself is invariant under the transition; only the realised channel — surface contact, tensile support, or open-pathway acceleration — changes. This is the framework's reading of the regime classification of §7.2 and the operational basis on which the regime-transition tests of §9.4 are designed.

8. The Flagship Practical Prediction: r = 2

8.1. The Discrimination Region

All three branches of the C-family converge at full positive saturation (r □ 1) — this is why dense-object-in-air drop tests do not discriminate the family. They diverge progressively as r decreases. The C = 0 column produces |a/g| > 1 for every case where $\rho_o < \rho_m$ — an outcome inconsistent with observed bounded buoyant rise once added-mass effects are properly accounted for (McKee and Czarnecki, 2019). Only the C = 1 (ValerieX) branch is bounded throughout. The intermediate-falling regime (1 < r □ 5) is the experimentally optimal discrimination region: predictions differ by an experimentally accessible margin while both branches remain physically meaningful and within the dynamic range of accessible apparatus.

System	ρ_o (kg/m³)	ρ_m (kg/m³)	r	χ	C = 1 (a/g)	C = 0 (a/g)	C = 0.5 (a/g)
Air bubble in water	1.225	1000	1.23×10^{-3}	−0.9976	−0.9976	−815.3 ‡	−1.99 ‡
Volleyball in water	80	1000	0.080	−0.8519	−0.8519	−11.5 ‡	−1.59 ‡
Helium balloon in air	0.179	1.225	0.146	−0.7451	−0.7451	−5.84 ‡	−1.32 ‡
Ice in water	917	1000	0.917	−0.0433	−0.0433	−0.0905	−0.0586
Flagship: $\rho_o = 2\rho_m$	2000	1000	2.000	+0.3333	+0.3333	+0.5000	+0.4000
Rock in water	2700	1000	2.700	+0.4595	+0.4595	+0.6296	+0.5313
Lead ball in air	11340	1.225	9257	+0.99978	+0.99978	+0.99989	+0.99984

‡ Indicates $|a/g| > 1$, i.e. the strict object-normalised or sphere prediction exceeds the vacuum-limit ceiling. These divergent values are systematic outputs of the C = 0 (and C = 0.5) formulas whenever $\rho_o < \rho_m$, and are the visible signature of the bounded C = 1 branch within the family.

8.2. The Flagship Prediction at $\rho_o = 2\rho_m$

At r = 2, the C-family predictions separate by experimentally accessible margins:

Branch	C	a/g	a (m s⁻²)
Classical (no added-mass)	0	0.5000	4.903
Sphere (potential flow)	0.5	0.4000	3.923
ValerieX (cylinder ⊥ axis)	1	0.3333	3.269

The C = 0 vs C = 1 separation is approximately $0.167g \approx 1.63$ m s^{-2} (~33% of g). This is an order of magnitude larger than the systematic error of any modern motion-tracking apparatus and is resolvable on commodity high-speed video at ≥ 240 fps. The C = 0.5 vs C = 1 (sphere vs cylinder) separation is approximately $0.067g \approx 0.65$ m s^{-2} (~6.7% of g) and requires ≥ 1000 fps imaging with sub-millimetre tracking precision: at t = 30 ms after release this corresponds to a position difference of approximately 0.3 mm between the two predictions.

8.3. Existing Literature Anchors

McKee and Czarnecki (2019) report buoyant-rise initial-acceleration measurements for light spheres in water, and find that the observed accelerations are reproduced only when the participating-medium-load renormalisation $(\rho_o + 0.5\rho_m)V$ is applied to the effective inertia. This is exactly the C = 0.5 sphere branch of the C-family. Their measurement therefore stands as a positive published anchor for one specific branch of the framework. The C = 0 column produces $|a/g| > 1$ throughout the buoyant-rise regime (r < 1), which contradicts observation:

bounded buoyant rise does not exceed g in magnitude. McKee and Czarnecki's data require the sphere branch C = 0.5 specifically. The experimental gap that this framework's flagship test is designed to fill is clean $\rho_o \approx 2\rho_m$ initial-acceleration data for cylinder-⊥-axis (C = 1) and capsule (intermediate C) bodies; the sphere branch is already supported.

8.4. Validation and Failure Criteria

The C-family validation programme returns a failure signal — the geometry-aware general law and the C-family structure of classical added-mass theory are challenged together — if any of the following hold robustly across multiple clean experiments:

- F1. Intermediate-density unconstrained initial acceleration (r ≈ 2) consistently matches a = g/2 (C = 0, no medium participation) for cylinder-class bodies even when added-mass effects are properly accounted for, contradicting both the C = 1 prediction and the broader added-mass literature.
- F2. Shape-controlled tests show no systematic difference between sphere, capsule, and cylinder initial accelerations at matched density, contradicting the geometry-dependent C-family structure.
- F3. Buoyant rise of light objects (r □ 1) consistently produces |a/g| > 1 in the early-time window, in line with strict object-normalisation and against the bounded prediction.
- F4. Near-equilibrium (r ≈ 1) or saturation ($r \to 0$, $r \to \infty$) regimes deviate systematically from gχ.

The programme returns a positive signal — the geometry-aware general law and the ValerieX organisation are validated together — if the inverse holds: cylinder-⊥-axis initial accelerations track gχ (C = 1), sphere initial accelerations track the C = 0.5 branch, capsule bodies trace intermediate values along the predicted C(L/D) curve, |a/g| < 1 holds robustly across the full range of finite densities, and the §8 predictions match measurements within combined experimental and added-mass uncertainty.

Apollo 15 / Galileo equivalence (vacuum limit, $\rho_m \to 0$) is already established and is not a C-family discriminator: in the vacuum limit the participating medium load $C\rho_m$ vanishes for every C and all branches collapse to a = g. The C-family validation lives at intermediate density and finite ρ_m.

8.5. Motion-Engine Reading: Early-Time Geometry Separation at Fixed Density Ratio

The flagship test of §8.2 is the experimental signature of the motion-engine identity. At fixed density ratio $r = \rho_o / \rho_m = 2$, ValerieX predicts that early-time acceleration is not determined by density contrast alone in a realised finite medium. Density contrast supplies the available drive; geometry sets the coupling branch through C. The geometry-aware general law at r = 2 reduces to

$a / g = 1 / (2 + C),$

giving the following ordering by geometry:

- Sphere ($C = 0.5$): $a/g = 0.4 \approx 3.92\ \mathrm{m\ s^{-2}}$;
- Capsule ($0.5 < C < 1$): $0.333 < a/g < 0.4$, with the L/D dependence given by the prolate-spheroid curve of §6.4;
- Cylinder ⊥ axis ($C = 1$): $a/g = 0.333 \approx 3.27\ \mathrm{m\ s^{-2}}$.

The motion-engine prediction is then direct:

> ***At identical density ratio, identical volume, identical medium, and identical release conditions, early-time acceleration should order by coupling geometry: sphere fastest, capsule intermediate, cylinder slowest.***

This is not a contradiction of classical added-mass theory; it is ValerieX's motion-engine reading of it. The novelty is that the same observable result is interpreted as density-drive plus geometry-dependent coupling, rather than as a sum of separate force categories. The capsule $C(L/D)$ curve of §6.4 — which predicts a continuous monotonic rise of C from 0.5 toward 1 as cylindrical-section aspect ratio increases — converts the binary sphere-vs-cylinder ordering into a continuous-parameter falsification target for the same motion-engine identity. McKee and Czarnecki (2019) provide the existing positive published anchor for the $C = 0.5$ sphere branch; the targeted $r = 2$ measurements with paired sphere–capsule–cylinder bodies fill the experimental gap on the $C = 1$ cylinder ⊥ axis branch and the capsule continuum between them.

9. Experimental Protocol Summary

This section consolidates the practical laboratory protocol developed in full in Volume IV. The C-family validation tests, in order of decisive power for the geometry-dependent coupling structure, are: (1) intermediate-density acceleration test at $r = 2$; (2) sphere–cylinder–capsule geometry test; (3) constrained / supported / unconstrained regime-transition tests; and (4) an exploratory torsion configuration recorded as a regime-classification investigation only (not a C-family discriminator). The first three are the falsifiable core of the manual.

9.1. General Laboratory Rules

9.1.1. Identify the regime first

Before any measurement, classify the test condition: constrained (blocked by rigid surface — surface force / scale reading), supported (held from above, pathway open below — tension / torsion / suspension signal), or unconstrained (pathway open, no support — acceleration / motion). The same density contrast can produce different measured signatures depending on whether motion is blocked, held, or free; every experiment must state its regime before interpretation.

9.1.2. Drag-timescale estimation (Reynolds-based)

For a body of characteristic length L moving at velocity v in a medium of density ρ_m and dynamic viscosity η, $Re = \rho_m v L / \eta$. As an order-of-magnitude estimate, the velocity at which drag equals 10% of the net driving force is $v_{10} \approx \sqrt{(0.2 |\rho_o - \rho_m| g L / (C_d \rho_m))}$. For a 4 cm sphere in water at $\rho_o = 2\rho_m$, this gives $v_{10} \approx 0.2$–0.3 m s^{-1} and Re ≈ 8 000–12 000. For a body released from rest under the C = 1 prediction a ≈ g/3, the time to reach v_{10} is $t_{10} \approx 60$–90 ms for centimetre-scale bodies in water. Compute t_{10} for each test geometry and density pair, and trim the fitting window to t □ $t_{10} / 2$ to keep the drag correction below 5% during the fit.

9.1.3. Early-time measurement window

The fit window is bounded below by release-transient timescales (typically 5–20 ms) and above by $t_{10} / 2$. For centimetre-scale bodies in water at r = 2 the resulting window is approximately 20–40 ms. Within this window, fit position to $y(t) = y_0 + v_0 t + \frac{1}{2}at^2$ and extract a from the quadratic coefficient; verify that the residuals do not show systematic curvature. Frame rate ≥ 240 fps gives 5–10 frames within a 20–40 ms window — acceptable but tight; 1 000 fps gives 20–40 frames and materially improves the uncertainty on a. Sensitivity of the fitted acceleration to window length should be tested and reported.

9.1.4. Release mechanism

Release the body fully submerged, not at the surface (eliminates surface-tension transients and air-cavity entrainment); use a matched-density holder that opens cleanly without imparting angular momentum (an electromagnetic gate or a split sleeve held closed by a pin pulled vertically clear of the path is acceptable; squeezing or rotating mechanisms are not); ensure the body is at rest at the moment of release (settle for ≥ 60 s after any disturbance); place the body so that the camera frame captures the full fit window before the body crosses any wall standoff threshold (≥ 5 body diameters from any wall). Discard the first 5–20 ms after release from the fit and verify with high-frame-rate playback that the body is moving cleanly without rotation before the fit window begins.

9.1.5. Density-measurement tolerances

Target ±1% on each of ρ_o and ρ_m, propagated as a combined ±2% on r and corresponding ±1% on the predicted a. Measure ρ_m by hydrometer or by mass-balance of a calibrated displacement vessel (±0.5%); measure ρ_o per body by mass and by water-displacement volume (±1%) — do not assume the bulk material density of the printer feedstock or moulded plastic. Record temperature with each density measurement (water density varies ≈0.05% per °C near room temperature). Reject any body whose individually measured density deviates from the target by more than 1.5%.

9.1.6. Imaging resolution at r = 2

The two discrimination targets at r = 2 differ by an order of magnitude in their imaging-precision requirements. The C = 0 vs C = 1 separation (~0.167g, ~1.63 m s^{-2}) corresponds to a position difference of approximately 0.7 mm at the upper edge of a 30 ms fitting window. This is comfortably resolvable on commodity 240 fps imaging with millimetre-scale calibration. The C = 0.5 vs C = 1 separation (~0.067g) corresponds to only about 0.3 mm at t = 30 ms; resolving this requires frame rate ≥ 1 000 fps, calibration at ≤ 0.2 mm per pixel, rigid camera mounting, sub-pixel centroid tracking, and confirmed sub-millimetre repeatability of the release mechanism.

9.1.7. Composite Uncertainty Budget

This subsection composes the dominant systematics into a propagated uncertainty on the fitted early-time acceleration a at r = 2, so that experimental claims and discrimination margins can be stated against an explicit budget. The reference values below are for centimetre-scale bodies in water at $\rho_o = 2\rho_m$ using 1 000 fps imaging with 0.2 mm/pixel calibration; they should be re-evaluated for any other configuration. Each source is to be propagated through to the fitted a/g and reported alongside the measurement, not assumed at the apparatus level.

Source	Reference contribution to fitted a	Cross-reference
Density tolerance on ρ_o, ρ_m (each ±1%)	≤ 1% on the predicted a (≈ 0.03 m s⁻²); affects the prediction line, not the measurement	§9.1.5
Release transient (first 5–20 ms discarded)	≤ 1% on a (≈ 0.04 m s⁻²) for trials passing no-rotation playback check	§9.1.4
Orientation drift during fit window (cylinder ⊥ axis)	≤ 2% on a (≈ 0.07 m s⁻²) when trials with > 5° drift are rejected	—
Wall and finite-container effects (standoff ≥ 5 body diameters)	≤ 3% on a (≈ 0.10 m s⁻²) at minimum standoff; reducing with larger standoff	Brennen 1982 §3.3
Drag onset within fit window (t □ t_{10}/2)	≤ 2% on a (≈ 0.07 m s⁻²) given the sub-window stability check	§9.1.2, §9.1.3
Tracking resolution (1 000 fps, sub-pixel centroid, σ_y ≈ 0.05 mm)	≈ 1.5% on a (≈ 0.05 m s⁻²) over a 30 ms fit window	§9.1.6
Frame-rate / time-base calibration	Negligible at ≤ 10^{-4} relative	—

Treating the per-trial sources as approximately independent and combining in quadrature, the single-trial uncertainty on a at r = 2 with cylinder ⊥ axis bodies and 1 000 fps imaging is approximately

$$\sigma\_a \text{ (single trial)} \approx \sqrt{0.04^2 + 0.07^2 + 0.10^2 + 0.07^2 + 0.05^2}\ \text{m s}^{-2} \approx 0.15\ \text{m s}^{-2},$$

corresponding to ≈ 4–5% of the C = 1 prediction (a = 3.27 m s⁻²) and ≈ 4% of the C = 0.5 prediction (a = 3.92 m s⁻²). With the minimum-evidence requirement of ≥ 10 trials per condition (§9.7), the standard error of the mean reduces this to ≈ 1.5% per branch.

Resolvability against the C-family separations:

- $C = 0$ vs $C = 1$ separation (≈ 1.63 m s^{-2}) is resolved at $> 10\sigma$ on the SEM at 1 000 fps and $> 5\sigma$ at 240 fps; this is the primary flagship discriminator and is comfortably accessible on commodity equipment.

- $C = 0.5$ vs $C = 1$ separation (≈ 0.65 m s^{-2}) is resolved at ≈ 4–5σ on the SEM at 1 000 fps with the budget above; this is tight, and the geometry-controlled discriminator depends on holding each source within the reference contributions stated.

- Continuous-parameter capsule C(L/D) test (§6.4) requires the same imaging chain as the $C = 0.5$ vs $C = 1$ separation; the predicted ordering a_sphere(r) > a_capsule(r) > a_cylinder(r) at $r > 1$ is detectable provided per-shape SEM remains below half the smallest predicted increment between adjacent L/D points.

Failure mode. If the per-trial uncertainty exceeds 5% of a — for example because frame rate is below 1 000 fps, calibration is coarser than 0.2 mm/pixel, wall standoff is insufficient, the release-transient discard window is too short, or orientation control is inadequate — the $C = 0.5$ vs $C = 1$ sphere/cylinder discriminator and the capsule continuum become inconclusive. The $C = 0$ vs $C = 1$ flagship discriminator remains accessible at lower precision (240 fps, 1 mm calibration), with the trade-off noted in §9.1.6. Any experimental claim must report both the budgeted contributions used and the per-trial and SEM uncertainties achieved, so that the resolvability of the relevant separation can be assessed independently of the central values.

9.2. Experiment 1 — Intermediate-Density Flagship Test

Aqueous medium with controlled density (water + NaCl/glycerol, $\rho_m \approx 1000$–1500 kg m^{-3}) and machined or 3D-printed test bodies of matched density $\rho_o = 2\rho_m$. Release from rest in a tank large enough to suppress wall effects (lateral and bottom standoff ≥ 5 body diameters; release depth such that the body crosses ≥ 3 diameters before any wall interaction). Capture motion with high-speed video (≥ 240 fps) or an onboard accelerometer; fit the initial slope of v(t) over the first 20–100 ms before drag dominates. Run paired sphere and cylinder bodies of identical volume and density to test the geometry-aware extension simultaneously.

Result	Interpretation
$a \approx g/3$	C-family validation: matches $C = 1$ (cylinder $\perp$ axis) branch
$a \approx g/2$	C-family validation: matches $C = 0$ (no medium participation) branch — challenges added-mass coupling
a between g/3 and g/2	Indicates intermediate participation coefficient — within the C-family but between branches
inconsistent / noisy	Repeat with improved release, tracking, and controls

Vacuum-limit control note. Free-fall comparisons performed under near-vacuum conditions are not discriminators between the C-family branches. As $\rho_m \to 0$ the participating medium load $C\rho_m$ vanishes for any value of C, the medium's viscous resistance also vanishes, and all branches collapse to $a = g$. Vacuum tests therefore serve as positive controls for the apparatus and for the saturation limit of the C-family, but cannot discriminate between competing predictions: the discrimination is intrinsically a finite-medium measurement at intermediate density and shape-controlled coupling.

9.3. Experiment 2 — Shape-Controlled C-Family Test

Same fluid, same ρ_o/ρ_m, same initial-acceleration measurement window. Predicted branches: cylinder ⊥ axis tracks C = 1 (a = gχ); sphere tracks C = 0.5. Predicted gap at r = 2 is approximately $\Delta a \approx 0.067g$ (~0.66 m s^{-2}) — well above experimental noise. The hemisphere-ended capsule extends the test to a continuous-parameter discriminator: by varying the cylindrical-section length while holding the cross-sectional radius and density fixed, a capsule sweeps the participation coefficient across the predicted range 0.5 < C_capsule < 1 (the C(L/D) curve of §6.4). Short capsules approach the sphere limit; long capsules approach the perpendicular-cylinder limit. Any monotonic capsule-length trend in early-time a/g, at fixed ρ_o and ρ_m, is direct evidence for the C-family structure and cannot be reproduced by a single fixed-coefficient model.

From the measured acceleration, fit the participation coefficient via $C = [g(r - 1) / a] - r$. Falsification: the C-family validation programme returns a failure signal — challenging both ValerieX and the classical added-mass theory it is consistent with — if sphere, capsule, and cylinder give no measurable separation; if the cylinder does not approach the C = 1 branch; if the sphere does not separate toward the C = 0.5 branch; or if the measured order is repeatedly opposite to prediction.

9.4. Experiments 3–5 — Regime-Transition Tests

Three regime-transition tests demonstrate the regime classification with everyday equipment. Experiment 3 (co-free-fall zero-reading test): place a test mass on a digital scale inside a protective drop box, drop the box, and record the scale reading during fall. Expected: scale reading goes to near-zero during the unconstrained-regime phase and returns when the system lands and re-enters the constrained regime. The χ-drive itself is unchanged; the regime change is the cause of the reading change. Experiment 4 (surface vs suspension): record the same object on a digital scale (constrained-regime reading: realised weight) and hung from a spring scale (supported-regime reading: transmitted force of density / tension). The numerical readings can be close; under ValerieX they record structurally different quantities. Experiment 5 (accelerating-frame transition): track the continuous decrease of scale reading as a system transitions from rest (constrained) toward free fall (unconstrained), demonstrating that the available χ-drive is invariant under the transition while the realised expression changes with pathway condition.

9.5. Experiment 6 — Exploratory Torsion Configuration

This investigation is presented as an exploratory regime-classification observation rather than as a quantitative test or competing-prediction discriminator. Under the regime classification of §7, suspended torsion-balance configurations occupy the supported regime — a structural classification that follows from the operational criterion of §7.3. No quantitative density-state competing prediction for the magnitude or scaling of the observed Cavendish torque is asserted in this paper; whether such a prediction can be developed is treated as an open question (V2 §5.5 and Appendix A). The cross-method consistency of measured G across torsion-balance, free-fall, atom-interferometry, lunar laser ranging, satellite-orbit, and Earth-tide determinations (Gillies, 1997, and subsequent precision-G literature) is acknowledged as genuine empirical confirmation of the conventional Newtonian gravitational interpretation, and is not contested. The configuration variations recorded in V4 §9.3–§9.5 are exploratory variations of interest that would accompany any future quantitative density-state development of the supported-regime torque, not falsifiable tests in the present formulation. The constrained-regime configuration is structurally difficult to realise without losing the torsion measurement itself: if the test masses are supported from below by a rigid platform that takes their weight, the torsion fibre no longer carries net vertical load and the angular degree of freedom against which torque is read is not equivalent to the standard configuration.

9.6. Experiment 7 — Medium-Substitution Discriminator

This test examines whether the early-time acceleration in the unconstrained regime is set by the density-state contrast ($\rho_o - \rho_m$) between object and medium alone, or whether non-density properties of the medium (viscosity, compressibility, dielectric constant, molecular structure) contribute an additional, independently observable term over and above that contrast. At fixed $r = 2$ and fixed geometry (cylinder ⊥ axis, $C = 1$), the C-family early-time prediction depends only on the density ratio r and the geometry coefficient C, so it is invariant under any change of medium that holds ρ_m fixed.

Use two media of identical density $\rho_m \approx 1000$ kg m^{-3} but different composition: pure water and an aqueous glycerol/NaCl mixture tuned to the same ρ_m within ±0.1%. Use the identical $r = 2$ cylinder. Predicted $a = g/3 \approx 3.269$ m s^{-2}, identical in both media. Measured difference within ±1% (≤ 0.05 m s^{-2}) supports the C-family early-time prediction under these conditions; a systematic difference correlated with non-density medium properties would challenge density-contrast sufficiency.

9.7. Minimum Evidence Standard

For a result to count as meaningful: at least 10 repeats per condition; density measurements recorded; temperature recorded; raw video retained; early-time fitting method stated; drag-dominated late-time data not used as initial acceleration; regime declared before interpretation; error bars shown; null or failed results included; mean, standard deviation, and confidence intervals reported for all measured accelerations; any systematic drift between trials investigated and documented.

9.8. Recommended Build Order

Stage 1 — Easy demonstrations (regime logic): surface vs suspension; co-free-fall scale drop; accelerating-frame transition. Stage 2 — Core discriminator: intermediate-density $r = 2$ test (the

C = 1 bounded branch against the C = 0 strict object-normalised limit). Stage 3 — Geometry discriminator: sphere vs capsule vs cylinder, including the continuous C(L/D) capsule sweep. Stage 4 — Density-contrast independence: medium-substitution test at the same r = 2 cylinder. Stage 5 — Exploratory torsion configuration (optional, regime-classification only).

9.9. Pass/Fail Summary

Test	Validation supports the framework if…	Validation challenges the framework if…
r = 2 discriminator	Measured a approaches g/3 (C = 1) for cylinder ⊥ axis bodies; tracks predicted C-family branch for each geometry	Repeatedly approaches g/2 (C = 0) for cylinder ⊥ axis bodies — would also challenge classical added-mass theory
Sphere / cylinder / capsule	Fitted C separates by shape; capsule traces continuous interpolation 0.5 < C < 1 along predicted C(L/D)	No repeatable shape dependence — would challenge classical added-mass theory broadly
Co-free-fall	Scale reading collapses during free fall	Scale reading remains unchanged
Surface / suspension	Same χ gives different regime signature	Regime has no measurable relevance
Torsion configuration	Exploratory only — no falsifiable density-state competing prediction asserted	Cross-method G consistency (Gillies, 1997) confirms the conventional interpretation
Medium-substitution	Same a within ±1% (≤ 0.05 m s^{-2}) across two media of identical ρ_m but different composition	Systematic, repeatable difference correlated with non-density medium properties

10. Scope and Limitations

The present formulation applies specifically to vertical motion in a surrounding environment and to the role of density-state disequilibrium in generating and organising that motion.

The scope is deliberately restricted to phenomena that can be directly observed, measured, and repeated under everyday or accessible laboratory conditions: rest, rise, fall, flotation, buoyant motion, terminal behaviour in real media, and intermediate-density and shape-controlled discrimination regimes. Phenomena that are not directly accessible to repeatable everyday measurement — orbital dynamics, planetary mechanics, satellite motion, interplanetary trajectories, gravitational lensing, cosmological-scale structure, and the precision-G measurement programme — lie outside this scope and are neither addressed nor displaced by the framework. Vertical direction in ValerieX is the local resolution direction set by the gradient structure of the surrounding medium; it is not asserted as a universal cosmological direction. The framework is offered as an organisation of the vertical-motion observables that any reader can in principle reproduce.

10.1. What the Framework Treats

- Equilibrium and neutral suspension.
- Rise and fall in media.
- Vacuum-limit free-fall behaviour.
- Reinterpretation of weight, buoyancy, and gravitational response under the regime classification.
- Terminal behaviour through realised-motion constraint.
- Geometry-aware realised acceleration through participating medium load.
- Thermal, acoustic, and pressure-driven motion through density-state modulation.

10.2. What the Framework Does Not Yet Provide

- A first-principles derivation of g (treated as observed, not derived).
- Cosmological-scale extensions (out of scope).
- Quantitative reproduction of precision-G measurements within the density-state framework (named explicitly as future work).
- Full transient drag integration is a defined extension developed in V3 §8.3 and V4 §11; the core C-family law supplies the early-time drive and coupling structure at $t = 0^{+}$, before drag closure dominates. The present consolidated paper deliberately isolates early-time behaviour so that density contrast and geometry-dependent coupling can be tested cleanly before terminal effects dominate.
- CFD-grade capsule C(L/D) predictions: the §6.4 prolate-spheroid mapping is a first-order approximation; a CFD or boundary-element computation that handles the hemispherical end-caps explicitly would refine the curve, particularly at small L/D where end-cap effects are largest in proportion.

10.3. Honest Statement of Position

The paper does not reject existing measurements. Weighing-scale readings, torsion-balance deflections, atom-interferometric phase shifts, and precision determinations of G are all real, reproducible observables, and the paper takes them as such. The paper does not claim that ValerieX has quantitatively reproduced the numerical value of G; that is named explicitly as future work. The paper does not reinterpret cosmological-scale phenomena, strongly non-inertial systems, or configurations whose pathway condition is itself ambiguous. The paper does not derive the environmental scale g from first principles.

What the paper does is supply (i) a symmetry-based derivation of the bounded contrast variable χ and Valerie's Law; (ii) a regime classification of terrestrial laboratory configurations; (iii) the geometry-aware C-family extension and its capsule continuous discriminator; and (iv) a falsifiable experimental programme — the C-family validation tests at r = 2 and across paired sphere–capsule–cylinder geometries — by which the structural claims could be tested. These are stated as boundaries of the present formulation rather than as defects. Each represents a defined route for further development.

11. Conclusion

ValerieX is presented as a symmetry-based, motion-first reorganisation of classical buoyancy and added-mass behaviour, grounded in density-state disequilibrium and governed by Valerie's Law,

$$a = g \cdot (\rho_o - \rho_m) / (\rho_o + \rho_m) = g\chi.$$

From a minimal ontological base, the framework derives a bounded, antisymmetric, scale-neutral law of available vertical motion; proves the uniqueness of χ as the lowest-degree rational function meeting the four foundational conditions; and characterises every higher-degree solution as χ multiplied by an even, scale-neutral correction. The framework recovers the principal observables of vertical motion — rest, rise, fall, vacuum free fall, weight-response, buoyancy-response, and terminal behaviour — from one law plus medium participation rather than from a stack of separate primitive force terms.

Geometry enters through the participation coefficient C, and the bounded form is recovered exactly at the C = 1 branch of the recognised classical added-mass family — the participating-medium-load coefficient for a circular cylinder moving perpendicular to its axis in inviscid potential flow (Brennen, 1982; Lamb, 1932; Kelvin, 1871). The terrestrial scale $g = 9.80665$ m s^{-2} (NIST CODATA) is treated as the observed ceiling of realised vertical particle acceleration under full contrast, interpreted as the pathway-availability ceiling at which available motion is fully realised. Realised motion is organised by a regime classification with three operationally distinct regimes — constrained, supported, and unconstrained — each defined by a single directly observable pathway condition.

Three experimental routes isolate early-time coupling behaviour and discriminate the C-family branches: the intermediate-density unconstrained measurement at $\rho_o = 2\rho_m$, where the C-family predicts a = g/3 (C = 1, cylinder ⊥ axis), a = 2g/5 (C = 0.5, sphere), and a = g/2 (C = 0, strict object-normalised limit); shape-controlled measurements with paired sphere–capsule–cylinder bodies, with capsule bodies tracing the continuous prolate-spheroid-derived C(L/D) curve; and the medium-substitution discriminator that probes density-contrast sufficiency at fixed r and geometry. McKee and Czarnecki (2019) provide a positive published anchor for the C = 0.5 sphere branch; the experimental gap to be filled is clean $\rho_o = 2\rho_m$ initial-acceleration data for the cylinder ⊥ axis (C = 1) branch and for the continuous-parameter capsule curve. The exploratory torsion configuration is recorded as a regime-classification investigation only and does not assert a quantitative density-state competing prediction for the Cavendish torque; the cross-method consistency of measured G across multiple independent methods (Gillies, 1997) is acknowledged as genuine empirical confirmation of the conventional Newtonian gravitational interpretation.

The intent of this paper is to set the reorganisation out cleanly, anchor it in observation and the established literature, and invite collaborative engagement with its structural contributions and its open questions. The framework is scope-limited throughout to vertical-motion phenomena that can be directly observed, measured, and reproduced in everyday and laboratory conditions. It does not extend to orbital, planetary, or cosmological scales; g is treated as observed, not derived; and vertical direction is treated as locally defined by the surrounding medium rather than as a universal absolute. Volumes I–IV remain the canonical technical record and are referenced throughout this paper as the supporting package for readers wishing to consult the full detail.

Each clause is an empirical claim that can be tested against observation, against the classical interpretation, or against the experimental programme set out in §9 and developed in full in Volume IV. The framework is offered for collaborative engagement on those terms.

> ***ValerieX does not reject the classical equations. It identifies a single motion-engine structure beneath them and invites the work of testing whether that structure holds.***

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