Volumetric Positioning State (VPS / 5DVNS)

A Deterministic Framework for State-Based Positioning and Navigation

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Date: February 2026

Executive Abstract

Positioning and navigation systems have historically been constructed around a single assumption: that location is best represented as a point within an absolute reference frame. This assumption underlies global navigation satellite systems (GNSS), inertial navigation systems (INS), simultaneous localization and mapping (SLAM), and most contemporary autonomous navigation architectures.

This paper introduces a different premise.

Rather than treating position as a point in space, the Volumetric Positioning State (VPS / 5DVNS) models position as a deterministic state embedded within a bounded volume, defined by geometric admissibility and contextual integrity rather than absolute coordinates.

In this framework, position is not continuously corrected toward an external reference. Instead, positional coherence is maintained through volumetric consistency under constraints. Guidance, stability, and navigation outputs emerge from the persistence of admissible states over time.

The framework is domain-invariant, reference-frame independent, and robust to signal loss, vertical ambiguity, and map unavailability. It reframes navigation from coordinate accuracy to state integrity, enabling coherent operation across surface, subsurface, indoor, underwater, orbital, and non-physical domains.

This document formalizes the VPS state model, its invariance properties, and its interpretive shift, without prescribing implementation details or domain-specific realizations.

1. Limits of Point-Based Positioning

Classical positioning systems represent location as a point:

$$P(t) = (x, y, z)$$

This formulation assumes:

- A stable external reference frame
- A privileged origin
- A continuous ability to correct drift
- A clear separation between position and uncertainty

While effective in open and well-instrumented environments, point-based positioning exhibits structural fragility when:

- External references degrade or disappear
- Vertical ambiguity dominates (e.g., subsurface, indoor, underwater)
- Environments are dynamic, constrained, or unstructured
- Mapping is incomplete, outdated, or impossible

In such cases, systems compensate by layering probabilistic corrections, sensor fusion, or increasingly complex maps—without addressing the underlying representational assumption.

The core limitation is not sensor quality or computation.

It is the choice of point as the primitive of position.

2. From Coordinates to State Integrity

The VPS framework replaces point-based localization with state-based embedding.

Position is not asked as “Where am I?”

It is evaluated as “Is my current state admissible within the volume I inhabit?”

Formally, position is expressed as:

$$S(t) = [x, y, d \mid V]$$

Where:

- x, y represent lateral embedding within a bounded manifold
- d represents scalar progression (depth, distance, phase, or corridor advancement)
- V is a volumetric context vector encoding:
  - geometry
  - constraints
  - uncertainty
  - stability
  - field or resonance behavior

The state is deterministic under bounded uncertainty.

Position emerges from volumetric consistency, not absolute reference alignment.

In this model:

- Coordinates are observations, not authorities
- Sensors inform state evolution, but do not define position
- Drift is not eliminated, but made explicit and bounded
- Loss of external reference does not imply loss of coherence

Position becomes a property of state survivability under constraints over time.

3. Invariance Properties

The VPS formulation exhibits the following invariances:

- Frame-independent: no dependence on fixed maps, magnetic north, or global orientation

- Robust to signal loss: coherence maintained without continuous external correction
- Robust to vertical ambiguity: depth and progression decoupled from Cartesian altitude
- Deterministic under bounded uncertainty: uncertainty is internalized, not externalized
- Domain-agnostic: applicable across surface, subsurface, indoor, underwater, orbital, and abstract environments

These properties arise from the geometry of the state itself, not from redundancy or correction frequency.

4. Interpretive Shift

The framework introduces two fundamental transformations:

- From coordinate tracking → state integrity
- From position accuracy → positional confidence

Navigation guidance is not prescribed.

It emerges from the admissible evolution of states within constraints.

This shifts navigation from optimization toward targets to maintenance of coherence.

Implementation Note

This document describes an operational-level construct.

Implementations may vary by domain, resolution, sensing modality, and risk profile. Certain structural aspects of the framework are subject to prior art disclosures and active patent filings and are intentionally described here at a conceptual level.

5. State Evolution and Admissibility

Within the VPS framework, navigation is the evolution of a state rather than the traversal of coordinates.

State evolution is governed by admissibility:

A state is valid if it remains geometrically and contextually consistent with the constraints encoded in V.

Formally, state transition does not seek an optimal target. It evaluates whether the next state remains inside the admissible volume defined by:

- Geometric boundaries
- Environmental constraints
- Dynamic stability conditions
- Temporal progression limits

This introduces a critical distinction:

- Trajectory is not planned in advance
- Path viability is evaluated continuously

As long as the evolving state remains admissible, navigation proceeds. When admissibility degrades, guidance emerges as a corrective signal—not toward a coordinate, but toward restored coherence.

In this sense, navigation is not command-driven.

It is constraint-driven.

6. Role of the Volumetric Context Vector (V)

The volumetric context vector V is not metadata.

It is a first-class component of the positional state.

Unlike traditional systems where uncertainty, constraints, or environmental factors are treated as error terms or auxiliary layers, VPS embeds them directly into the state definition.

The vector V may encode, depending on domain and implementation:

- Geometric constraints (corridors, boundaries, exclusion zones)
- Stability margins (allowed deviation, tolerance envelopes)
- Uncertainty structure (bounded drift, sensor bias accumulation)
- Field behavior (electromagnetic, seismic, fluidic, or abstract fields)
- Resonance or persistence signatures

Crucially:

- V does not describe the environment
- V defines the conditions under which a state remains valid

This allows the system to reject impossible states deterministically, rather than correcting them probabilistically after failure.

7. Emergent Outputs and Downstream Guidance

All operational outputs in VPS are derived, not prescribed.

Typical emergent outputs include:

- Navigation guidance within constrained volumes
- Corridor and path stability estimation
- Predictive trajectory inference
- Collision, failure, or instability risk metrics
- Decision confidence signals
- Autonomy control primitives

These outputs are consequences of state evolution under constraints.

No map, waypoint, or route is required for these outputs to exist.

Guidance emerges when the system detects approaching loss of admissibility.

In this sense:

- Guidance is a symptom
- Stability is the objective

8. Separation of Integrity and Utility Layers

A defining architectural principle of VPS is the separation between:

- Integrity layers (state admissibility, coherence, bounded uncertainty)
- Utility layers (guidance, visualization, human interfaces)

This separation ensures that:

- The core state logic remains domain-invariant
- Consumer or operator guidance can vary freely
- Visualization does not influence state validity
- Human interpretation is downstream of machine coherence

This makes the framework suitable as a foundational positioning layer, rather than a domain-specific navigation tool.

9. Applicability Beyond Physical Space

The VPS formalism does not require physical space.

Any system that satisfies the following conditions may be modeled:

- States exist inside bounded constraints
- Transitions occur over time or progression
- Admissibility can be evaluated deterministically

This allows the same formalism to apply to:

- Autonomous agents operating in abstract decision spaces
- Multi-agent coordination under shared constraints
- Graph traversal with viability conditions
- Non-spatial state systems where “position” represents coherence

In such cases, x, y, d need not correspond to physical dimensions.

They represent embedding, progression, and phase inside a constrained manifold.

This extension is not metaphorical.

It is a direct consequence of the state definition.

10. Summary of the Shift

The VPS framework introduces a structural inversion:

Classical Navigation	VPS / 5DVNS
Point-based	State-based
Coordinate-driven	Constraint-driven
Map-dependent	Map-agnostic
Correction-centric	Integrity-centric
Accuracy-focused	Confidence-focused

Position becomes what remains coherent, not what is measured.

Closing Remark

The VPS framework does not compete with existing navigation systems.

It reframes the layer at which positioning is defined.

It treats navigation not as the pursuit of coordinates, but as the maintenance of admissible state evolution.

This makes it suitable as a universal integrity layer for navigation, autonomy, and state-based reasoning across domains.