

Event-Driven Geolocation Validation for Rural Autonomous Systems: TrustGeoScore & Geolocation Name System (GNS)

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Here's a brief overview of the presenter, Juan A. Padilla:

- PhD student in Computer Science and Engineering at the University of Puerto Rico, Mayagüez
- Recipient of the NSF CSGrad4US Fellowship
- Co-founder of Technology Partners — a 28-year-old IT company based in Puerto Rico; serves as Chief Strategy Officer leading R&D
- Research focus: geolocation systems, autonomous applications, and trust-aware computing
- Inventor of the Geolocation Name System (GNS)
- Led multiple federally funded R&D projects: NSF, DoD, FEMA, U.S. Census
- Research goal: make geolocation reliable for real-world and autonomous systems



Research Interests



Geolocation reliability and "Reliable Places"



Autonomous systems (drones, logistics, infrastructure)



Trust-aware computing and AI systems



Rural and infrastructure-sparse environments

Current Projects



Geolocation Name System (GNS) — contextual location identity



TrustGeoScore — dynamic geolocation reliability



Statewide drone infrastructure for Puerto Rico



AI-enabled drone applications: disaster response, agriculture, infrastructure monitoring

 **Vision:** "Enable autonomous systems to operate safely using trusted geolocations instead of raw coordinates"

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Autonomous Systems Depend on Geolocation — But It Is Unreliable

Rural Geolocation Challenges

- **Poor Maps**
Rural areas lack up-to-date, granular cartographic data
- **Weak Addressing**
Civic addresses are sparse, inconsistent, or entirely absent
- **GNSS Drift**
Signal instability leads to unreliable coordinate readings

⚠ Safety Risks

✘ Failed Missions

💰 High Operational Cost

Consequence

Systems assume coordinates are correct — an assumption that frequently fails in practice.



Coordinates Are Not Enough

A single coordinate fails to capture the operational complexity of real-world locations.

What One Coordinate Cannot Represent...

Entrances

Gate vs. service
access

Landing Zones

Safe drone
touchdown points

Access Paths

Navigable vs. obstructed routes

Civic Addresses Are Often...

Missing

Ambiguous

Inconsistent

📌 **Key Insight:** Geolocation must include **context** and **reliability** — not just coordinates.



Research Goal: Make Geolocation Reliable for Autonomous Systems

We introduce two complementary contributions that together transform how autonomous systems interpret and trust location data.

GNS — Geolocation Name System

Contextual, hierarchical place identifiers that encode meaning beyond raw coordinates



TrustGeoScore

A dynamic, evidence-based reliability score continuously updated from real operational feedback

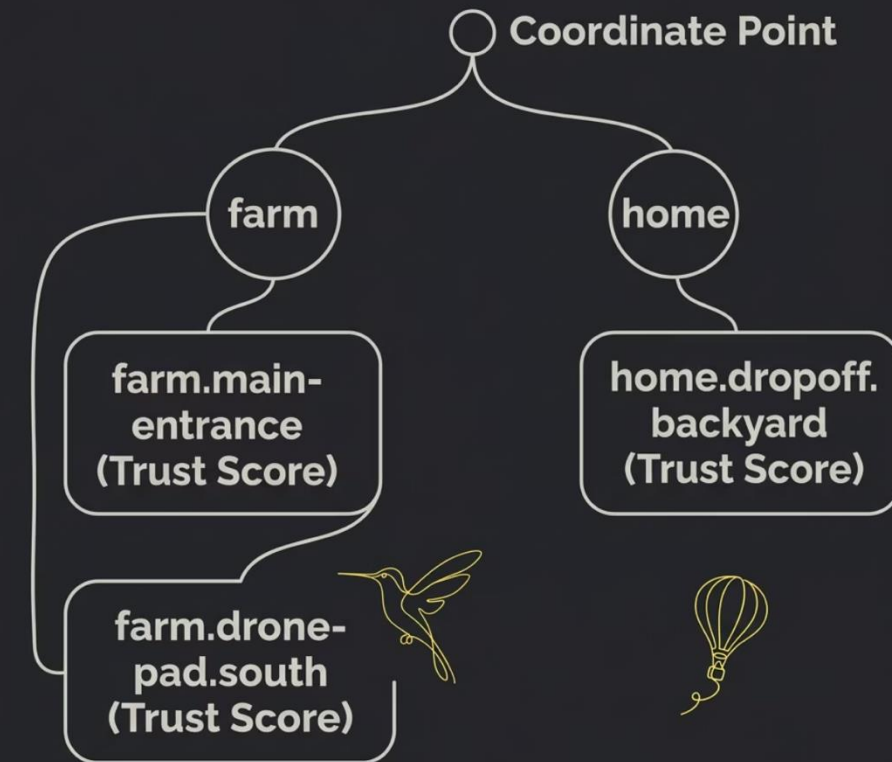
From Coordinates → to "Reliable Places"

Traditional Approach

One generic coordinate per property — no distinction between access points, zones, or roles.

Our Approach

Multiple meaningful sub-locations, each with its own identity and trust score.



farm.main-entrance

farm.drone-pad.south

home.dropoff.backyard

GNS — Geolocation Name System

GNS introduces **contextual geolocation namespaces** — structured identifiers that carry rich operational metadata alongside coordinates.



Coordinates

Precise latitude, longitude, and altitude with confidence bounds



Metadata

Location type, surface conditions, infrastructure details



Access Rules

Permitted vehicle types, time windows, clearance requirements



Trust Score

Dynamic reliability rating derived from real-world operational evidence



GNS enables systems to understand **what a place is** and **how reliable it is** — before committing to a mission.

TrustGeoScore — Dynamic Reliability Model

Trust is not assigned — it is **earned** through real-world evidence aggregated across multiple signal sources.

01

Drone Telemetry

Flight path deviation, landing accuracy, hover stability

02

IoT Sensor Signals

Environmental and infrastructure readings from co-located devices

03

GNSS Stability

Signal consistency and multipath interference measurements

04

Human Confirmations

Operator-validated corrections and field reports

05

Application Outcomes

Delivery success, inspection completion, mission result codes

Why Application Feedback Is the Most Important Signal

Operational Outcomes Speak Louder Than Sensors

When a real-world task succeeds at a location, it is the strongest possible confirmation that the location is **operationally correct** — not just geometrically plausible.

- ☐ **Core Principle:** The system learns from usage. Each mission outcome refines trust without manual labeling.



✓ Delivery Completed

✓ Drone Landed Successfully

✓ Inspection Finished

Trust Model — Two Key Components



By combining weighted multi-source aggregation with time-based decay, TrustGeoScore reflects **current operational reality** rather than historical assumptions — preventing stale locations from retaining undeserved trust.

Trust Behavior Over Time



Phase 1 — Initialization

Low trust by default; minimal evidence available



Phase 2 — Stabilization

Trust grows with consistent, successful usage



Phase 3 — Decay

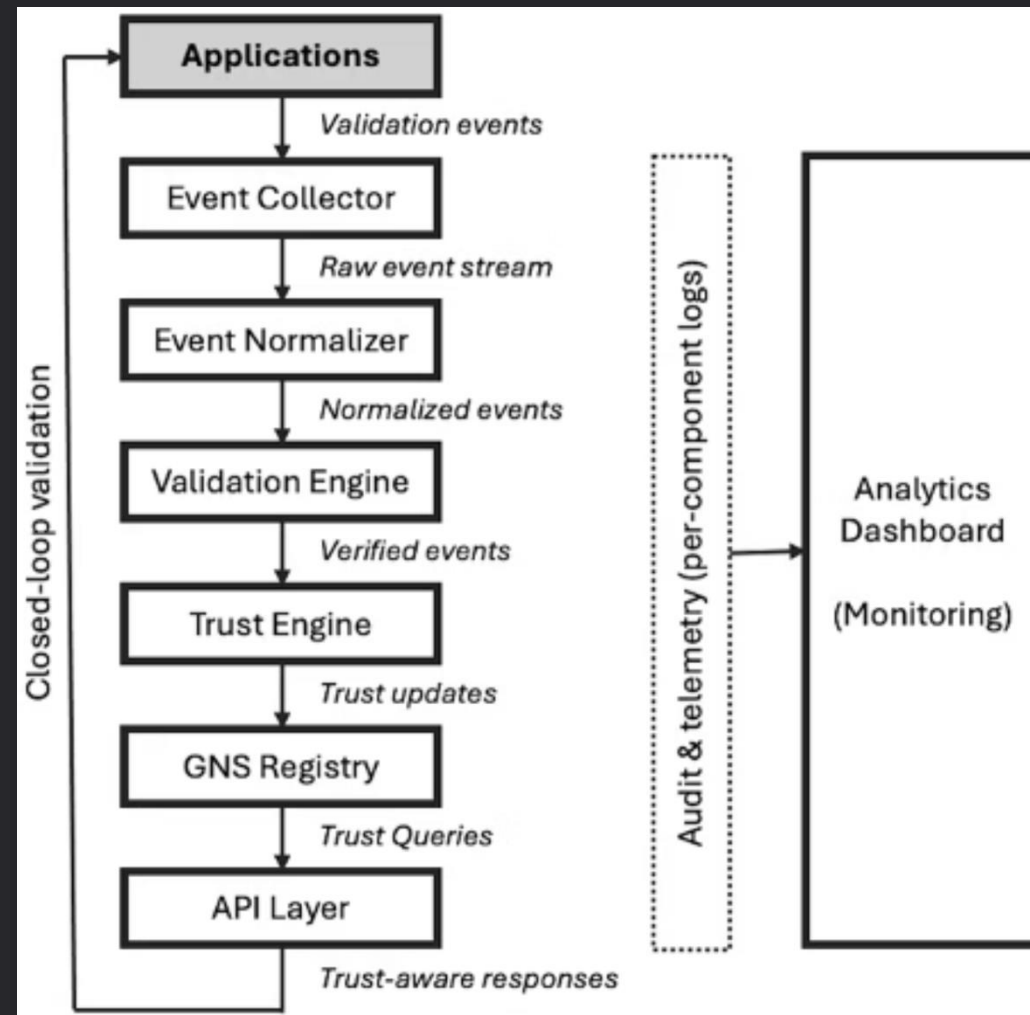
Trust decreases if the location goes unused or events conflict

Why This Matters

A location that was reliable last season may no longer be safe today. Temporal decay ensures outdated locations do not retain falsely high trust scores — a critical safety property for autonomous operations.

Trust reflects **current reality**, not history.

System Architecture — Event-Driven Pipeline



The architecture forms a closed-loop validation system:
operational use generates events → events validate locations → validation updates trust → updated trust improves the next operation.

Closed-Loop Validation — The Core Design Idea



Use Location

System selects and navigates to a named GNS location




Confirm Outcome

Application reports success or failure post-mission



Update Trust

TrustGeoScore is recalculated with new evidence

 No manual labeling required. The system improves automatically with every operation.





Application: Trust-Aware Drone Operations

1

Pre-Mission

Query candidate GNS locations; select highest-trust option for the task

2

In-Flight

Adjust behavior dynamically if real-time trust signals indicate low confidence

3

Post-Mission

Record outcome; update TrustGeoScore to reflect actual operational result

Application: Trust-Aware Routing

Modified Dijkstra's Algorithm

Standard shortest-path routing is augmented with a **trust penalty** on edges connected to low-reliability locations.

The Trade-Off

Routes may be slightly longer in distance — but significantly more reliable in execution. For autonomous systems, **reliability outweighs brevity**.



Standard Dijkstra:
Shortest path,
high risk,
unreliable
nodes.



Trust-Aware Dijkstra:
Avoids risk,
high success
rate.

Low Trust → High Penalty

High Trust → Low Penalty

Expected Impact — Projected Improvements

Simulation-based projections across three operational domains demonstrate substantial reliability gains when TrustGeoScore is integrated.

40–60%

↓ Landing Errors

Logistics & last-mile delivery
operations

25–45%

↑ Task Consistency

Precision agriculture and field
inspection

50–70%

↓ Navigation Failures

Emergency response and first
responder routing

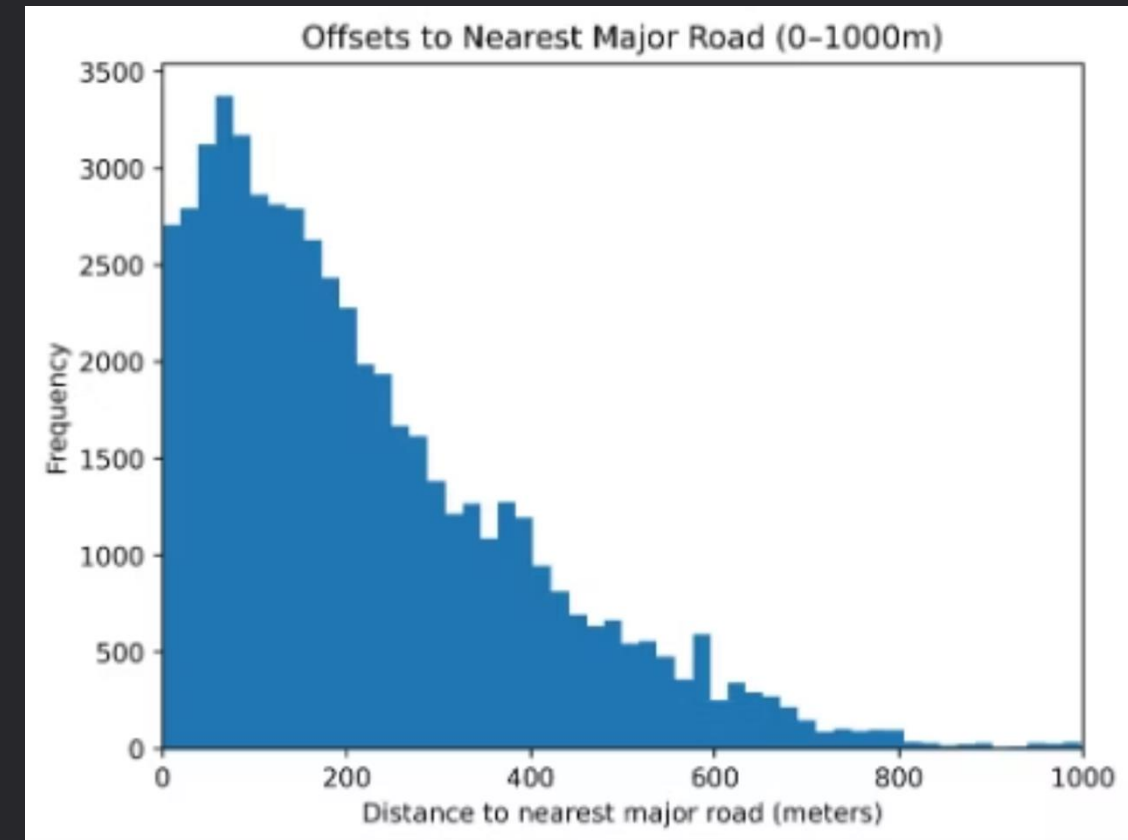
📄 Reliability becomes **measurable, trackable, and improvable** — not an assumed property of the map.

Empirical Validation — USDA Dataset Analysis

Dataset Overview

Key Findings

- Locations cluster tightly — median inter-point distance ~4.5 m
- Most points are near *some* road, but not major roads
- Proximity to infrastructure does not guarantee navigability



32,019

Geolocations analyzed

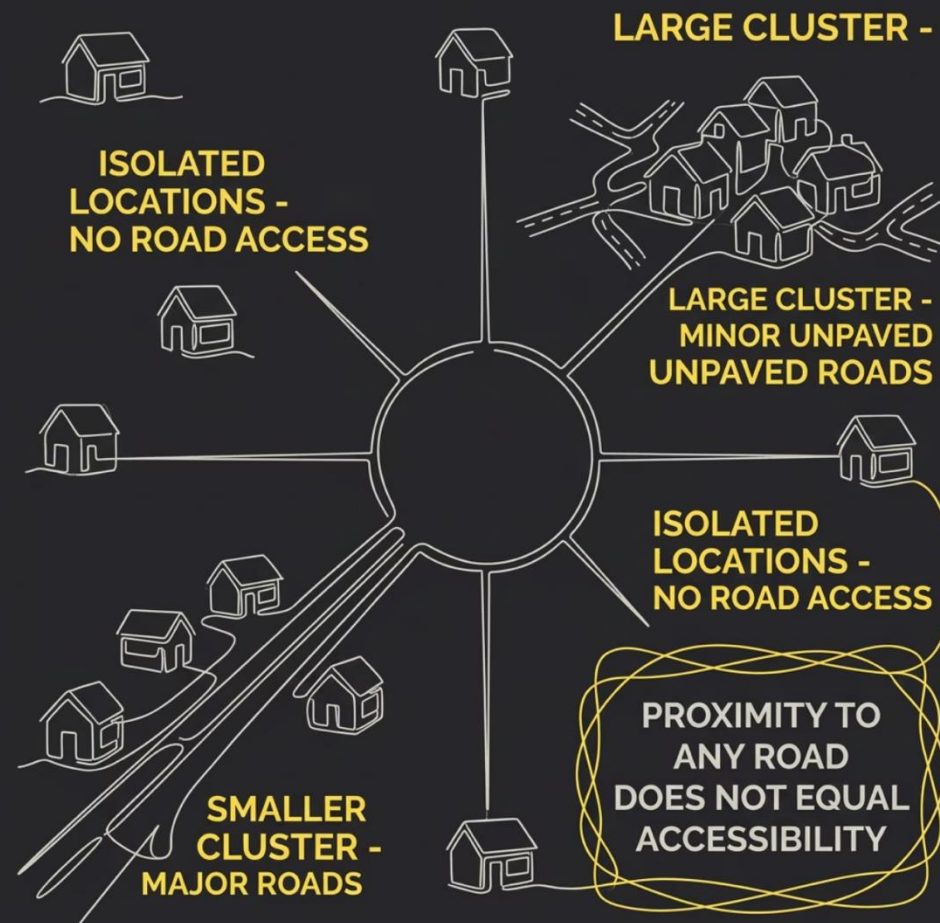
199.7 km²

Coverage area

160 /km²

Location density

Key Insight from the Data



Proximity \neq Accessibility

A location may be close to a road on the map — yet completely inaccessible to a delivery vehicle or drone in practice.

📄 **Conclusion:** Access depends on **context**, not just coordinates. GNS captures this distinction explicitly.

Close to some road

True for most rural locations in the dataset

Close to a major road

True for far fewer — access path varies dramatically

Limitations — Where the System Has Boundaries

Event Volume Dependency

Trust scores require sufficient operational history — sparse locations converge slowly

Cold Start Problem

New or infrequently visited locations begin with minimal trust and limited evidence

Parameter Tuning

Decay rates and source weights require domain-specific calibration

Sensor Reliability

Faulty or adversarial sensors can inject misleading evidence into the trust pipeline



Design Philosophy

Every architectural decision reflects a deliberate set of priorities — chosen because autonomous systems operating in the real world cannot afford black-box behavior or brittle binary decisions.

Interpretability over Black-Box AI

Trust scores are explainable — every value traces back to evidence sources

Gradual Trust over Binary Decisions

Reliability exists on a spectrum; the system reflects that nuance

Real-World Feedback over Assumptions

Operational outcomes override static map data

Safety over Optimization

When uncertain, choose the reliable path — not the fastest one



Conclusion — Geolocation Is Not a Coordinate

Geolocation is a dynamic, evidence-based concept — one that must reflect operational reality, not just cartographic data.

TrustGeoScore

Makes reliability measurable, trackable, and continuously updated from real operations

GNS

Provides contextual, named identifiers that encode meaning, access rules, and trust

Together

Enable safer, more reliable autonomous operations in rural and underserved environments

Future Work

Next Research Steps

01

Real-World Deployments

Validate system performance in live rural operations with production hardware

03

Trust Convergence Studies

Characterize how quickly scores stabilize under varying event frequencies

02

Mission Success Measurement

Quantify the relationship between TrustGeoScore thresholds and task completion rates

04

Urban Environment Extension

Adapt the model to denser, higher-event-rate urban geolocation contexts



From Coordinates to Reliable Places

Autonomous systems navigating the real world need more than a location on a map.

- 📌 Not just location — but **trusted** location.
That is the foundation of safe autonomy.