Nick Clark · Published July 30, 2026 · PDF

When GPS Is Gone and the Fleet Still Has to Move

At 06:40 on an ordinary Wednesday, the satellite fixes a terminal operations lead relies on to place every straddle carrier in her container yard stop arriving. Nothing is broken. Her tractors still run, her cranes still lift, and her yard system still knows which box belongs on which stack. What it no longer knows is where anything is. Until the fixes return she cannot authorize a single automated move, and the vessel alongside her berth is working a rotation that will not wait. U.S. Provisional Application No. 64/049,409 describes a mesh-derived coordinate primitive in which participating agents produce a shared coordinate reference frame cooperatively, through inter-agent ranging, anchor observation admission, and governance-credentialed frame definition, without dependence on any specific external positioning infrastructure.

06:40 in the Yard

The terminal operations lead at a mid-sized inland container port takes the first call of the shift from the tower. Every satellite fix in her yard has gone to nothing inside about ninety seconds. Not degraded, not drifting: absent. Her straddle carriers have stopped where they stood. Her automated stacking cranes are holding above the rows they were working. The vessel at her berth has an exchange of roughly nine hundred moves and a departure time set by a rotation that was fixed weeks ago in another country.

Nothing in her yard is broken. Every machine has power, every drive is healthy, every box in her stacks still has a slot address in her terminal operating system. She can see, on the wall display, exactly which container is supposed to go where. What she cannot do is tell any one of her machines where it is standing, or where it is standing relative to the machine forty meters away from it, and her safety case does not permit an automated move under an unresolved position.

By 07:15 she has done what her runbook tells her to do. She has put the yard into manual, which means human drivers in cabs, which means she is now running a fraction of her normal move rate with the equipment she has crewed for a Wednesday. By 08:00 she is calling the line agent about the berth window.

What the Berth Window Takes With It

Her window does not slip. It ends. Her vessel sails on its rotation whether or not the last two hundred boxes are aboard, because the next port in that rotation has its own window and its own line-up. The containers she could not load go to the stack and wait for a call that, in her yard's booking pattern, is a week out. The reefer boxes among them need power and monitoring for that week. The transshipment boxes miss their onward connection at a port she does not control and cannot rebook.

None of that is recoverable in her yard by working faster on Thursday. Her yard has a fixed number of crane hours and a fixed number of hours of daylight labor, and Thursday was already committed to Thursday's vessel. Catching up would require capacity she does not have, so the cost lands as a permanent hole in the week rather than as a delay that closes.

There is a second loss, quieter, that she notices in the following days. Her incident review asks her to reconstruct where every machine was during the outage window and what each one believed about its own position at the moment it stopped. Her records for that interval are the fixes her receivers reported, and her receivers reported nothing.

She can produce the last good fix before 06:40 and the first good fix after the outage cleared, and between them her yard has no position history at all. She cannot demonstrate to her insurer, to the port authority, or to her own board that no machine was ever in a place it should not have been. For her the absence is permanent, since she has no later moment at which that missing interval could be measured.

Why Her Fallback Is Not a Fallback

Her yard was designed around a single source of position, and every layer she built on top of it inherited that dependency. When that source is gone from her yard, none of her layers degrade gracefully; in her setup they stop at once.

She has inertial units on her carriers, and for a few minutes they are useful. But a dead-reckoned position in her yard drifts, and drift with no bound on it is worse than no position for her purposes, because her safety case cannot distinguish a carrier that knows it is lost from one that is confidently wrong by three meters in a lane that is three and a half meters wide. Were her machines able to check each other, the drift would be correctable. As her deployment is configured today, each machine's estimate is private to that machine, and there is nothing in her yard that reconciles them.

She has surveyed points. Her stack corners, her crane rails, and her gate structures were all surveyed to millimeters when the terminal was commissioned, and those numbers are still true. What she does not have is any way for a carrier standing in the yard at 06:40 to use them, because the one bridge her deployment ever built between a surveyed point and a moving machine was the satellite fix.

She also cannot tell, on the morning itself, what she is dealing with. Her receivers report an absence, and in her tooling that absence reads identically whether it came from a transmitter on a truck outside her fence, from atmospheric conditions, or from a fault in her own antenna distribution. Her escalation path branches hard on that

question and she has no evidence to choose the branch with. If it were spoofing rather than denial, her machines would have accepted a plausible wrong position and moved on it, and she would not have found out until something touched something else.

Coordinates the Yard Produces For Itself

The filing describes a mesh-derived coordinate system as an architectural primitive of the governed spatial mesh: a shared coordinate reference frame produced cooperatively by participating mesh agents through inter-agent ranging, anchor observation admission, and governance-credentialed frame definition, without dependence on any specific external positioning infrastructure. In accordance with an embodiment, the primitive operates over the shared environmental world view as substrate, and the coordinate-bearing observations it produces are reachable by any governance-credentialed consumer through the governed mesh.

The described primitive includes a governance-credentialed inter-agent ranging mechanism that produces range observations between participating agents through at least one of a plurality of ranging modalities, and an anchor observation admission interface that admits governance-credentialed anchor position contributions. A cooperative localization engine determines agent positions by multilateration from admitted range observations and anchor positions. Where direct-anchor ranging is insufficient, a transitive localization extender is described as producing positions through neighbor references instead. A coordinate-frame specifier defines the frame type, origin, orientation, scale, and temporal association of the resulting system.

The disclosure describes uncertainty as carried rather than discarded. A precision-and-uncertainty propagator is described as propagating ranging precision and ranging covariance through the localization chain to produce per-position uncertainty estimates, and an ambiguity-resolution mechanism selects among multiple solutions where the multilateration admits more than one. In accordance with an embodiment, the primitive composes with the capability envelope through coordinate-precision-

bounded operation and with the confidence-governed execution primitive through positioning-confidence-governed actuation, so that what a unit is permitted to do can be conditioned on how well its position is known rather than on whether a position exists at all.

For the failure modes the operations lead cannot presently tell apart, the disclosure describes an adversarial-range rejection mechanism that rejects spoofed, injected, or otherwise inadmissible range observations, with each range observation authenticated through the governance-chain continuity identity and evaluated through the composite admissibility evaluator. In the described arrangement, each contributing range observation carries a continuity-based identity and an authority credential of its own rather than resting on a static identifier. Where the governance policy defines the admissibility thresholds, the outcome follows those thresholds; the disclosure frames rejection as a governed determination rather than as an unconditional property.

Two further described elements bear on a morning like hers. An anchor-less bootstrap mechanism is described as producing a relative-only coordinate frame when no anchor observations are available, and an evidential-fusion mechanism is described as combining mesh-derived positions with externally-sourced positions, including satellite navigation, inertial dead-reckoning, and visual-inertial odometry, through the composite admissibility evaluator. A self-healing topology maintainer updates the coordinate graph under agent failure, removal, or addition. Throughout, a coordinate-lineage recorder is described as recording each range observation, localization event, frame definition, uncertainty update, ambiguity resolution, rejection event, federation event, and consumption event in the governance chain lineage field.

The filing also describes a reference-node densification mechanism, stating that the precision of mesh-derived coordinates is bounded by ranging modality accuracy and reference-node density within ranging distance of consuming agents, and describing a densification-need detector that identifies regions where precision falls below

governance-policy-defined thresholds, together with candidate-deployment evaluation, deployment-admissibility evaluation, a deployment executor, and a post-densification integration engine.

Where the Disclosure Stops

The bound the filing states about precision is a real bound for her. Mesh-derived precision in her yard would be limited by the accuracy of whatever ranging modality her equipment carries and by how many reference nodes sit within ranging distance of the carrier that needs a position, and no part of the disclosure changes that arithmetic for her particular lane widths. Densification is described as an answer to thin coverage, but for her it would be a physical answer: nodes would have to be placed across her rows, and the disclosure describes deployment intervals as bounded by the densification form chosen.

Nor does the described architecture reach backward. Her missing Wednesday stays missing. Lineage recording is described for coordinate determinations the mechanism itself produces, so it would begin to help her from the point her deployment participates, not before.

The anchor-less bootstrap is described as producing a relative-only frame. In her situation that would mean her carriers could know their geometry with respect to one another before they could place that geometry against her surveyed stack addresses, and closing that gap is described as depending on admitted anchor observations rather than on the bootstrap alone.

Finally, the coordinate chapter is scoped to coordinates. The filing treats the temporal reference frame as a separate primitive that the coordinate primitive composes with, so her clock question is answered elsewhere in the filing and not by the mechanism

described here. And nothing in the disclosure speaks to what her port authority, her insurer, or her safety regulator would accept as evidence of position during an outage; that determination is theirs and not the architecture's.

Disclosure Scope

This article describes subject matter disclosed in U.S. Provisional Application No. 64/049,409. It is a technical description written for practitioners, and the operating scenario in it is illustrative. Nothing in this article characterizes the scope of any claim, and nothing in it constitutes an admission regarding the state of the art.

Mesh-Derived Coordinates (/mesh-coordinates)

All 49 steps → (/inventive-steps)

Cooperative localization with credentialed ranges. Densification on demand.

Provisional application

PRIMARY TECHNICAL DISCLOSURE

- Mesh-Derived Coordinates: Cooperative Localization With On-Demand Densification (/articles/mesh-derived-coordinates-cooperative-localization-with-on-demand-densification)

SECONDARY TECHNICAL

- Multi-Modality Cooperative Ranging (/articles/mesh-coordinates/multi-modality-ranging)
- Cooperative Localization Across Mesh Units (/articles/mesh-coordinates/cooperative-localization)
- Relative Frame Bootstrap Without Absolute Reference (/articles/mesh-coordinates/relative-frame-bootstrap)
- Credentialed Range Observations With Lineage (/articles/mesh-coordinates/credentialed-range-observations)
- Lineage-Bound Multilateration (/articles/mesh-coordinates/lineage-bound-multilateration)
- Anti-Spoofed Observation Rejection (/articles/mesh-coordinates/anti-spoofed-rejection)

- Reference Node Densification (/articles/mesh-coordinates/reference-node-densification)
- Airdroppable and Rapidly-Deployable Reference Nodes (/articles/mesh-coordinates/airdroppable-deployable-nodes)
- Coordinate Frame Federation Across Mesh Regions (/articles/mesh-coordinates/coordinate-frame-federation)
- Cross-Jurisdictional Coordinate Alignment (/articles/mesh-coordinates/cross-jurisdictional-alignment)

APPLICATIONS · GENERAL

- How to Position Forces When GPS Is Jammed: GNSS-Denied Defense PNT (/articles/mesh-coordinates/gnss-denied-defense-positioning)
- GNSS-Denied Positioning for Underground Mining, Tunneling, and Subterranean Operations (/articles/mesh-coordinates/subterranean-operations-positioning)
- Urban Canyon Positioning Without GNSS Lock: Cooperative Ranging for City Streets (/articles/mesh-coordinates/urban-canyon-civilian-positioning)
- GNSS-Independent Positioning for Autonomous Ships at Sea (/articles/mesh-coordinates/autonomous-shipping-ocean-positioning)
- DDoS-Resilient Positioning: Jamming and Spoofing Defense Through Mesh Cooperation (/articles/mesh-coordinates/ddos-resilient-positioning)
- Drone Airspace Integration: GNSS-Independent BVLOS Positioning with Credentialed Lineage (/articles/mesh-coordinates/drone-airspace-integration)
- Indoor Medical Positioning for HIPAA-Compliant Hospital RTLS (/articles/mesh-coordinates/indoor-medical-positioning)
- High-Accuracy Positioning for Mass-Market Mobile Without Reliable GNSS (/articles/mesh-coordinates/sub-meter-mass-market)
- **When GPS Is Gone and the Fleet Still Has to Move (/articles/mesh-coordinates/mesh-coordinates-stakes)**

APPLICATIONS · SPECIFIC

- Hexagon SmartNet Alternative: Governed Cooperative Positioning (/articles/mesh-coordinates/hexagon-smartnet)
- Locata Alternative: Cooperative Mesh Coordinates Beyond Site-Specific Pseudolites (/articles/mesh-coordinates/locata-positioning)
- NextNav Pinnacle vs Cooperative Multi-Modality Positioning (/articles/mesh-coordinates/nextnav-pinnacle)
- Apple UWB vs Governed Mesh Coordinates: The Cooperative Positioning Layer Above U1 (/articles/mesh-coordinates/apple-uwb)

- Decawave/Qorvo UWB Alternative: Governed Cooperative-Ranging Substrate (/articles/mesh-coordinates/decawave-uwb)
- Septentrio GNSS vs Governed Cooperative Positioning (/articles/mesh-coordinates/septentrio-gnss)
- Topcon Positioning Alternative: GNSS-Independent Mesh Coordinates (/articles/mesh-coordinates/topcon-positioning)
- u-blox GNSS Alternative: Cooperative, GNSS-Independent Positioning (/articles/mesh-coordinates/u-blox-gnss)

HOW-TO GUIDES

- How to Get Accurate Positioning Without GPS: A Mesh-Derived Coordinate Architecture (/articles/guides/positioning-without-gps)
- How to Get Positioning Underground or Indoors Where GPS Fails (/articles/guides/positioning-underground-and-indoors)
- How to Get Sub-Meter Positioning for Autonomous Shipping Without GPS (/articles/guides/sub-meter-positioning-for-autonomous-shipping)

TERMINOLOGY

- mesh-derived coordinate (/glossary#mesh-derived-coordinate)

Mesh-Derived Coordinates overview → (/mesh-coordinates)