

# How to Get Sub-Meter Positioning for Autonomous Shipping Without GPS

If you are building autonomous surface vessels, port tugs, or container-handling equipment that has to berth, transit a channel, or maneuver in a harbor with meter-or-better precision, GPS alone will not carry you: the fix degrades near steel superstructure and quay cranes, it is jammable, and it gives you no way to authenticate what you receive. This guide describes an architectural approach that resolves position from a governed mesh of credentialed reference observations and inter-agent ranging instead of a satellite constellation, and how you would densify that mesh to reach sub-meter precision where you need it. It is an architecture disclosed in U.S. Provisional Application No. 64/049,409, the Mesh-Derived Coordinates inventive step, not a shipping library you can install.

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## What You Are Building

You are building a positioning system for vessels and port equipment that has to know where it is to within roughly a meter or better, in exactly the places where a satellite fix is least trustworthy. A container ship threading a narrow channel, an autonomous surface vessel holding a lane in a busy harbor, a tug easing a hull against a fender, a straddle carrier placing a box on a quay: all of them need precise, continuous position, and all of them operate in an environment full of steel, cranes, and reflective water where GPS multipath, attenuation, and jamming are routine rather than exceptional.

The specific search intent is: "how do I get sub-meter positioning for an autonomous vessel when I cannot rely on GPS?" The naive answer is "use RTK GPS" or "add more sensors." Those help, but they either inherit the satellite dependency or leave you with a per-vessel perception problem that no single unit can solve past its own sensor horizon. What you actually want is a coordinate frame that comes from the port and the vessels themselves, that you can make more precise on demand where precision matters most, and that authenticates every measurement it consumes.

That is the shape of the approach disclosed in U.S. Provisional Application No. 64/049,409. The rest of this guide walks through that architecture and how you would build it yourself. It is an architecture, not a product you download.

## **Why the Obvious Approaches Fall Short**

The standard answers each have a real, structural limit worth stating accurately and neutrally.

**Global satellite navigation (GPS, and the wider GNSS family).** These operate on broadcast signals from centrally operated constellations. Acquiring that signal is a precondition for positioning, so denial of the signal precludes positioning. Near large steel hulls, quay cranes, and harbor structures the signal is attenuated and multipath-corrupted, and outdoors it can be jammed or spoofed because a receiver trusts a pseudo-random-noise code it cannot independently authenticate. This is the shape of the system, not a defect you can patch around at the receiver.

**Differential and assisted positioning (RTK, DGPS).** These reach centimeter-to-decimeter accuracy by layering reference-station networks, maintained by a positioning-service operator, on top of the satellite fix. Where they work they are genuinely precise. But they inherit the satellite dependency and add a dependency on an external service operator and its reference-station infrastructure. Lose the sky or lose the operator link and you are back to nothing.

**Per-vessel sensor fusion (radar, lidar, cameras, inertial).** Every autonomous unit already carries a sensor suite and reconstructs the world from its own vantage point. This is expensive, redundant across units working the same berth, and structurally limited: no unit can perceive beyond its own sensor horizon, around an occluding hull, or through fog. Inertial dead-reckoning drifts without an external fix to bound it. These are useful inputs, but as a positioning frame they do not compose across units.

The common structural gap: in every case the coordinate frame is either imported from somewhere you do not control, or reconstructed privately by one unit that cannot see past itself. None of them produces a shared, authenticated, self-referencing frame owned by the port. The approach below does.

## **The Architecture**

The disclosed approach makes the coordinate frame itself a first-class architectural primitive: a **mesh-derived coordinate system** 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. Every mechanism below is drawn from the filing.

**Cooperative localization from ranging and anchors.** Participating agents (vessels, port equipment, and fixed reference devices) produce range observations against one another through a governance-credentialed inter-agent ranging mechanism. A cooperative localization engine determines agent positions by multilateration from the admitted range observations plus admitted anchor positions. Anchor positions enter through an anchor observation admission interface that admits governance-credentialed anchor position contributions. In a port, fixed reference devices and the passive credentialed markers the disclosure places in the environment serve as those anchor nodes.

**Transitive reach when direct anchors are out of range.** A vessel mid-channel may not be within ranging distance of any surveyed anchor. A transitive localization extender produces positions through neighbor references when direct-anchor ranging is insufficient, so a unit can localize against neighbors that are themselves localized. Position propagates through the mesh rather than requiring every unit to see an anchor directly.

**An explicitly defined frame, with propagated uncertainty.** A coordinate-frame specifier defines the frame's type, origin, orientation, scale, and temporal association, so the frame is a defined, governed object rather than an implicit convention, which is what lets independent parties agree on what a coordinate means. A precision-and-uncertainty propagator then carries ranging precision and ranging covariance through the localization chain, producing a per-position uncertainty estimate. This matters for shipping: a berthing maneuver needs a position you can trust to sub-meter, and the architecture hands you an explicit uncertainty on every fix rather than a bare coordinate. Where multilateration admits more than one solution, an ambiguity-resolution mechanism selects among them.

**Authenticated ranges, rejected spoofs.** Prior positioning systems that rely on static identifiers (satellite PRN codes, fixed beacon addresses) are vulnerable to identifier spoofing. Here, each range observation is authenticated through the governance-chain continuity identity of the disclosure with admissibility evaluation, and an adversarial-range rejection mechanism rejects spoofed, injected, or otherwise inadmissible range observations. An attacker cannot simply inject a false range and move your fix.

**Many ranging modalities in one graph.** Rather than being tied to a single modality, the primitive admits fifteen-plus ranging modalities integrated into a single coordinate graph, and can fuse mesh-derived positions with externally sourced

positions (satellite navigation, inertial dead-reckoning, visual-inertial odometry) through the disclosure's composite admissibility evaluator. GPS, where available and trusted, becomes one admissible input among many rather than the sole source.

**Reaching sub-meter: reference-node densification.** The disclosure is explicit that the precision of mesh-derived coordinates is bounded by ranging-modality accuracy and reference-node density within ranging distance of the consuming agent. To improve precision where you need it, a reference-node densification mechanism produces on-demand precision improvement by deploying additional reference nodes that integrate into the existing coordinate system. It comprises a densification-need detector that flags regions where precision falls below a governance-policy-defined threshold, a candidate-deployment evaluator that picks locations and modalities, an admissibility evaluator, a deployment executor (pre-placed, drone-positioned, vehicle-deployed, hand-placed, and other forms), a lineage recorder, and a post-densification integration engine. In a harbor this is how you get a berth or a channel to sub-meter while leaving open water at coarser precision: you densify the reference nodes exactly where the tolerance is tight.

**Anchors that get better as traffic passes.** The disclosure also describes a consensus-calibration mechanism: a marker's coordinate is set at installation (by surveyed GPS, measured offset, or approximate coordinates), then refined over time by consensus of equipped units' position readings as they pass, converging toward the statistical centroid of accumulated pass-readings under outlier filtering and authority-weighted accumulation. Your anchor network self-refines from ordinary port traffic.

**Reconstructible, bootstrappable, federatable.** A coordinate-lineage recorder records each range observation, localization event, frame definition, uncertainty update, ambiguity resolution, rejection, federation event, and consumption event in the governance-chain lineage field, so a position's derivation is deterministically reconstructible. Where anchors are entirely absent, an anchor-less bootstrap

mechanism produces a relative-only coordinate frame from zero-anchor conditions, and a coordinate-frame federation mechanism aligns two independently maintained systems, letting a vessel's onboard frame and a port's frame reconcile.

## How to Approach the Build

You are implementing this yourself; nothing here is a package you install. A workable order:

1. **Define the coordinate frame as an object first.** Before any ranging, specify frame type, origin, orientation, scale, and temporal association explicitly. A useful illustrative sketch of that object, faithful to the disclosure and nothing more:

```
Frame {  
    type, origin, orientation, scale,  
    temporal_association // ties positions to a shared time reference  
}
```

If two parties do not agree on this object, their coordinates do not mean the same thing.

2. **Stand up credentialed anchors.** Place fixed reference devices and credentialed markers at known points around berths and channel edges, each carrying an authority credential so its anchor contribution is admissible. Set initial coordinates by whatever method you have (surveyed RTK, measured offset, or approximate), and plan to let consensus calibration refine them from passing traffic.
3. **Build ranging as governed observations, not raw measurements.** Every range a unit produces should be a governed observation carrying identity, so it can be authenticated and, if spoofed, rejected. Treat range admission as an admissibility decision, not a trusted read.

**4. Implement the localization engine with uncertainty as a required output.**

Multilaterate from admitted ranges and anchors; propagate covariance through the chain; emit a per-position uncertainty with every fix. Add the transitive extender so units localize through localized neighbors when no anchor is in range, and the ambiguity resolver for multi-solution cases.

**5. Gate maneuvers on precision, and densify to meet it.** Decide the tolerance each task needs (channel transit coarser, berthing sub-meter). Wire the densification-need detector to that threshold, and deploy reference nodes where you fall short. Precision becomes something you provision where it is needed, not a single system-wide number.

**6. Record lineage from day one.** Log every range, localization, rejection, and consumption to the lineage field so any fix is reconstructible after the fact. In a regulated maritime setting this is what lets you show why a vessel believed it was where it was.

## **What This Does Not Give You**

This is an architecture disclosed in a patent filing, not a drop-in library, an SDK, or a benchmarked product. There is no package to install and nothing here "just works" out of the box; you implement the mechanisms yourself. The disclosure does not state accuracy figures, so treat "sub-meter" as a design target you reach through modality accuracy and reference-node density, not a guaranteed number the filing promises. Precision is explicitly bounded by ranging-modality accuracy and by reference-node density within ranging distance, so open water far from any densified region will be coarser, and a sparse mesh will not give you sub-meter no matter how you tune it. The architecture also assumes participating agents that carry governance credentials and can range against one another; it does not retrofit positioning onto uncooperative traffic that neither ranges nor credentials itself. And none of this removes the need for the rest of a safe autonomy stack: perception, collision avoidance, and vessel control remain your responsibility.

## Disclosure Scope

The approach described here, mesh-derived coordinates produced cooperatively through governance-credentialed inter-agent ranging, credentialed anchor admission, uncertainty propagation, adversarial-range rejection, and on-demand reference-node densification, is disclosed in U.S. Provisional Application No. 64/049,409. This guide is educational: it explains the architecture so a skilled developer can approach building it, and it is not a warranty, a performance guarantee, or an offer of software. Any third-party technologies named for context (GPS and the wider GNSS family, RTK and differential positioning, inertial and visual-inertial odometry) are described neutrally and are the property of their respective owners.

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## **Mesh-Derived Coordinates** (</mesh-coordinates>) [All 40 steps → /inventive-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 \(/articles/mesh-derived-coordinates-cooperative-localization-with-on-demand-densification\)](/articles/mesh-derived-coordinates-cooperative-localization-with-on-demand-densification)

### **SECONDARY TECHNICAL**

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

- [Anti-Spoofed Observation Rejection \(/articles/mesh-coordinates/anti-spoofed-rejection\)](/articles/mesh-coordinates/anti-spoofed-rejection)
- [Reference Node Densification \(/articles/mesh-coordinates/reference-node-densification\)](/articles/mesh-coordinates/reference-node-densification)
- [Airdroppable and Rapidly-Deployable Reference Nodes \(/articles/mesh-coordinates/airdroppable-deployable-nodes\)](/articles/mesh-coordinates/airdroppable-deployable-nodes)
- [Coordinate Frame Federation Across Mesh Regions \(/articles/mesh-coordinates/coordinate-frame-federation\)](/articles/mesh-coordinates/coordinate-frame-federation)
- [Cross-Jurisdictional Coordinate Alignment \(/articles/mesh-coordinates/cross-jurisdictional-alignment\)](/articles/mesh-coordinates/cross-jurisdictional-alignment)

## APPLICATIONS · GENERAL

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

## APPLICATIONS · SPECIFIC

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

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

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[Mesh-Derived Coordinates overview → \(/mesh-coordinates\)](/mesh-coordinates).