

Spatial OS for Maritime

Ships, Ports & Marine Infrastructure

The Complete Digital Twin & Smart Operations Platform

9 Stakeholder Groups • **40+ Use Cases** • **Jebel Ali, KAEC, JNPT, Mawani** • **IoT-Integrated Smart Ports**

Digital Twins | IoT Sensors | Geospatial Intelligence | Smart Operations | VR Training | Immersive Rooms | Real-Time Vessel Tracking

INDUSTRY WHITEPAPER

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Executive Summary

The maritime industry is experiencing unprecedented digital transformation. Ports operate 24/7 with complex vessel schedules, container flows, and equipment movements. Cruise lines compete on cabin experience. Shipyards design vessels under pressure from multiple stakeholders. Crew training demands safety compliance. Yet most stakeholders lack unified visualization of these spatial environments.

PROPVR's Spatial OS bridges this gap. From photorealistic digital twins of entire port campuses to real-time IoT-integrated smart operations dashboards, from VR crew training simulations to interactive cruise ship cabin walkthroughs, from AI-powered vessel traffic management to holographic yacht displays — each stakeholder gets immersive tools to visualize, plan, operate, and sell maritime assets.

The Challenge

Port authorities manage billion-dollar facilities without integrated spatial visualization. Planners use 2D CAD and printed charts. Cruise lines struggle to let potential customers experience cabins before purchase. Shipyards coordinate among naval architects, classification societies, and shipowners using fragmented tools. Crew training relies on classroom instruction and limited access to actual equipment. Mega-yacht brokers can't immerse ultra-high-net-worth clients in luxury vessel interiors. Vessel operators lack real-time geospatial intelligence of their fleet positions and hinterland connectivity.

Each challenge is tackled with disparate tools — CAD software, printed brochures, static websites, paper charts. No continuity. No speed. No ability to integrate IoT sensor data with spatial visualization.

The Solution: Spatial OS

One investment in photorealistic spatial content (via drone/LiDAR scanning, CAD integration, GIS overlay) unlocks every PROPVR product. Spatial Twin for offline port/vessel exploration with Walk/Fly modes. Spatial Stream for web-based tours. Spatial Cave for immersive

boardroom reviews. Spatial World for portfolio-level fleet/port intelligence. Spatial Map for geospatial shipping lane mapping and port catchment analysis. Spatial Agent for AI-powered port gate assistance. Spatial Lens for AR-assisted maintenance and training.

This whitepaper maps each of 9 maritime stakeholders to their ideal experiences, explains physical deployment of products (where hardware goes, why, how users interact), and quantifies ROI — from faster port expansion approvals to higher cruise cabin sales conversion to reduced crew training time to optimized vessel operations.

Industry Challenge: The Maritime Ecosystem Transformation

1. Port Expansion & Masterplanning Complexity

Ports like Jebel Ali (DP World, Dubai), King Abdullah Economic City Port (KAEC, Saudi Arabia), JNPT Nhava Sheva (Mumbai), and Mawani facilities are multi-billion-dollar expansions involving berth construction, container yard layout, warehouse positioning, and hinterland connectivity (rail, road, inland waterway links). Each stakeholder (port authority, shipping lines, cargo operators, government bodies, equipment suppliers, logistics partners) needs to understand and approve the final design.

Current workflow: PDF renderings, printed port layouts, 2D CAD files, physical site visits. Stakeholders can't quickly iterate feedback. Design changes (berth positioning, yard stacking configuration) are slow to model. Government approvals take 6-12 months because decision-makers can't visualize the operational impact of the final design.

- Port authorities struggle to gain consensus on berth allocation, yard layout, and gate positioning without a shared immersive 3D model.
- Naval architects and civil engineers spend weeks re-rendering dock design changes rather than rapidly prototyping variations.

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- Government approvers can't visualize vessel movements, container flows, or truck congestion without walking the actual space (impossible before completion).

2. Real-Time Port Operations & IoT Fragmentation

Modern ports deploy hundreds of IoT sensors: container tracking (RFID/GPS), crane sensors (load, position, cycle time), vessel AIS (Automatic Identification System) feeds, tide gauges, weather stations, air quality monitors, CCTV cameras, gate OCR readers, reefer container temperature sensors, and port basin water quality monitors. Yet these data streams are siloed — displayed in separate dashboards, not integrated into a unified spatial operations picture.

Port operators can't answer critical questions: Where exactly is container XYZ123 in the yard right now? Which cranes are overutilized and which are idle? What's the current vessel congestion at anchorage? Are reefer containers drifting out of spec? Is gate processing time above target? Are air quality sensors showing dangerous levels near residential zones? These answers require manually consulting 5-10 different systems.

- Vessel turnaround time averages 3-5 days in major ports; lack of spatial coordination costs USD 50,000+ per day per vessel.
- Reefer cargo loss due to temperature excursions: USD 5,000-20,000 per container; no real-time monitoring until too late.
- Yard congestion and truck queue buildup at gates cost USD 1,000-2,000 per truck per hour delay; no predictive dispatch.

3. Cruise Line Cabin Sales & Experience Gap

Cruise lines (Disney Cruise Line, Royal Caribbean, Carnival, and regional lines) compete on cabin experience and onboard amenities. Potential customers research cabins online using static photos and video clips. They can't experience the space — walk into a balcony cabin, feel the scale, see the ocean view, navigate the ship's public areas.

Cruise lines maintain mockup cabins in select cities, but most potential customers never visit. Online cabin browsers are clunky 2D or low-fidelity 3D. Result: Bookings trend toward legacy cruise lines or price-based decisions rather than experience-based upgrades.

- Premium cabin upsells (oceanview/balcony/suite) represent 40-60% of cruise line revenue but lack compelling pre-purchase immersive experience.
- Group/incentive travel buyers (corporate charters) make decisions on price sheets without viscerally experiencing the ship.

4. Shipyard Design Coordination & Multi-Stakeholder Complexity

Shipyards design vessels under pressure from naval architects, shipowners, classification societies (DNV, ABS, Lloyd's Register), flag states, and equipment suppliers. Design sign-off involves dozens of reviews and revisions. Stakeholders work from CAD files and 2D drawings, missing spatial opportunities and conflicts until late-stage design.

Design errors in engine room layout or cargo hold dimensions discovered late-stage cost millions in redesign and delay. No unified spatial review tool exists across all stakeholders.

- Ship design cycles: 18-24 months; 30-40% of time spent on iterative reviews and approvals.
- Late-stage design changes due to coordination gaps: USD 1-5M per change.

5. Crew Training & Safety Compliance

Maritime crew (deck officers, engineers, ratings) must be trained on vessel systems, safety procedures, and emergency response. Training is hands-on but limited by access to actual equipment and operational constraints. STCW (Standards of Training, Certification and Watchkeeping) mandates safety drills and certifications. Training relies on classroom instruction and occasional access to live vessels — inefficient and hard to scale.

New officers spend 12-24 months reaching full competency. Safety incidents often stem from inadequate training or procedure familiarity. Cross-training on new vessel types requires months of retraining.

- Training time-to-competency for new officers: 12-24 months.
- Safety drill certification: Crew complete mandated drills but forget procedures without ongoing reinforcement.

6. Mega-Yacht & Luxury Vessel Sales Barriers

Mega-yacht and luxury vessel brokers (Monaco, Dubai, Fort Lauderdale) sell ultra-high-net-worth clients vessels worth USD 50M-500M+. Clients are geographically dispersed (typically not willing to travel for broker meetings). Brokers rely on printed brochures, static photos, and occasional on-water viewings. A client in Singapore who is interested in a 150m superyacht anchored in Monaco can't easily experience the interior without a trans-continental journey.

Sales cycles drag. Clients don't commit without 'seeing' the vessel. Brokers lose sales to competitors who offer better pre-purchase visualization.

- Average mega-yacht sales cycle: 6-18 months; many deals fail due to buyer indecision (can't viscerally commit without seeing the space).

Spatial OS Platform Overview

PROPVR's Spatial OS is a unified platform: one spatial content investment (digital twin, CAD import, LiDAR scan, GIS integration) drives outputs across 14 products, deployed across 5 interaction modes (desktop, web, VR, AR, immersive rooms), with real-time IoT sensor integration capability.

Core Technology Stack

Spatial Twin is the foundation. It's a native EXE with photorealistic rendering, Walk mode (first-person navigation of ship interiors, port facilities, yard layouts), Fly mode (aerial overview of port basin, vessel approach channels, container yards), View mode (cinematic camera), day/night simulation, and gamification (click interactions, timeline scrubbing, annotations). The Twin integrates real-time IoT sensor overlays — container positions, crane movements, vessel positions, reefer temperatures, gate queues — updating live.

Every other product plugs into the Twin or a variant: Spatial Lite (web-only lightweight version), Spatial World (fleet/port portfolio dashboard), Spatial Stream (pixel streaming cloud EXE to browser), Spatial Cave (immersive 270°-360° projection), Spatial Table (tangible tabletop for port planning), Spatial Holo (glasses-free holographic display), Spatial Tour (VR), Spatial Lens (AR tablet), Spatial Agent (AI avatar), Spatial Drive (sales presentation), Spatial Map (geospatial intelligence with GIS overlay, shipping lane mapping, AIS integration, port catchment analysis).

Spatial OS Product Portfolio

| Product | Description | Key Capability |
|-----------------------|---|--|
| Spatial Twin | EXE-native 3D walkthrough with Walk/Fly/View modes, gamification, day/night sim | Photorealistic digital twin exploration |
| Spatial Lite | Web-based interactive project showcase | Browser-native property/facility showcase |
| Spatial World | Portfolio-level spatial intelligence platform | Multi-asset management and visualization |
| Spatial Stream | Pixel streaming technology | Host EXE experiences in cloud, stream to any browser |
| Spatial Touch | High-end GPU hardware device | Offline deployment for galleries/centres, zero latency |
| Spatial Tour | VR headset interior walkthroughs | Immersive VR exploration |
| Spatial Holo | Holographic model viewer | 3D holographic display without headsets |
| Spatial Cave | Immersive LED/projection room | Surround-display cinematic experience |
| Spatial Table | Interactive tangible tabletop | Tactile plan exploration and deep-dives |

| | | |
|----------------------|-------------------------------------|--|
| Spatial Agent | AI-powered avatar assistant | Conversational AI with spatial context |
| Spatial Lens | AR tablet viewer | Augmented reality overlay on physical spaces |
| Spatial Drive | Interactive sales presentation tool | Guided developer sales presentations |
| Spatial Map | Location intelligence and mapping | Geospatial context and neighbourhood data |

Stakeholder 1: Port Authority & Management

Port authorities (e.g., DP World for Jebel Ali, Mawani for Saudi Ports, JN Port Trust for JNPT, PSA International, Hutchison Ports) oversee entire port campuses: berths (container, breakbulk, cruise, dry dock, fuel loading), container yards, warehouses, inland rail sidings, road gateways, pilot stations, vessel service zones, and administrative facilities.

Deployment: Where Products Go, Why, How Used

Spatial World — Operations & Portfolio Dashboard

Deployment: Mounted in the port authority's 24/7 Operations Centre on a large multi-screen display (4K+ resolution). Also accessible on executive dashboards.

Why: Port authorities need bird's-eye view of the entire port campus in real-time — berth occupancy, vessel positions, container yard density, warehouse utilization, cargo flows, gate throughput, and weather/tide impacts.

How: Operations staff (duty manager, terminal controller, ground handler liaison) opens Spatial World. It shows the full port 3D model with live overlays:

- Green zones = operational, Red zones = maintenance/closure, Yellow = congested.
- Berth assignment board integrated with vessel schedules, pilot availability, and tugboat positions.
- Container yard heatmap showing density, dwell time distribution, equipment positions.
- Vessel queue at anchorage with ETA and berth assignment countdown.
- Reefer container monitoring — count of containers with temperature alerts by location.
- Gate throughput metrics — trucks processed per hour, average processing time, queue length.

Spatial Cave — Port Expansion & Investor Presentations

Deployment: Immersive 270°-360° LED/projection display (12 m × 8 m) in the port authority boardroom or a dedicated presentation theatre.

Why: Port expansions are multi-year, multi-billion-dollar projects. Authority executives, government officials, investors, and international shipping operators need to 'see' the future port to commit funding and volume commitments.

How: During a boardroom presentation, Spatial Cave displays the port's masterplan:

- Current state: Existing berths, yards, warehouses, with real-time vessel schedule simulation.
- Phase 1 (Year 1-3): New container terminal rises on screen, 6 new berths materialize, yard expands.
- Phase 2 (Year 4-7): Additional dry dock facilities, inland rail infrastructure, warehousing.
- Investor walkthrough: Camera flies over the port, showing vessel approach channel dredging, breakwater expansion, hinterland rail connection.
- ROI visualization: Timeline scrubbing shows revenue impact year-by-year as capacity comes online.
- Stakeholder impacts: Simulate increased vessel volume and resulting container throughput, gate load, rail utilization.

Impact: Investors are visually convinced. Government approvals accelerate from 12-month review cycles to 3-4 weeks.

Spatial Twin (Fly & Walk Modes) — Masterplan Review & Operations Planning

Deployment: Spatial Twin EXE running on authority's internal workstations or via Spatial Stream (pixel-streamed to web browser).

Why: Authority planners review the port's masterplan at extreme detail — berth spacing (critical for crane operations), yard stacking heights, warehouse internal layout, gate processing lanes, security fencing, environmental zones, and emergency access routes. They need to 'walk' through the port like an actual worker to identify operational flaws before construction.

How: Planners launch Spatial Twin and switch between modes:

- Fly mode: Aerial view of the entire port, rotation of container yards, zoom on berth layout to check crane spacing (overlapping boom zones), view approach channel from vessel perspective.
- Walk mode: First-person perspective from the main gate. Walk along the yard, inspecting stacking rules and equipment movement paths. Walk up a berth to inspect the quay wall and crane mounting positions. Walk into a warehouse to verify interior headroom and column spacing.
- Annotation tool: Planners click points of concern and leave comments ('Berth 5 crane boom conflicts with Berth 6 movement' or 'Container yard access road too narrow for RTG transit').

Impact: Operational flaws caught before construction. Crane conflicts, yard equipment collision zones, and process inefficiencies identified early. Saves USD 5-20M+ in rework.

Spatial Table — Port Layout Optimization & Berth Allocation Planning

Deployment: Interactive tangible tabletop (4 m × 3 m touch-responsive surface) in the planning department or operations centre.

Why: Port planning involves berth allocation, yard stacking strategy, gate positioning, rail siding placement, and crane placement. Multiple stakeholders (port authority, terminal operators, rail operators, cargo handlers) collaborate on optimal layout. A tabletop enables rapid iteration and consensus.

How: Stakeholders gather around Spatial Table. The port 2D floorplan is displayed (top-down view). Operators can:

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- Drag berth assignments, watching real-time impact on vessel turn-around time simulation — how many days to discharge?
 - Reposition container yard stacking zones, seeing impacts on equipment utilization and yard congestion heatmaps.
 - Move gate positions, testing truck queue simulation — does the new gate layout reduce congestion?
 - Place rail sidings and watch container flow from yard to rail loading — is the path efficient?
 - Visualize crane positioning and test boom swing zones for conflicts with other equipment.

Impact: 6-month planning cycles compressed to 1-2 weeks. All stakeholders iterate together, eliminating design conflicts and operational surprises.

Spatial Map — Geospatial Intelligence & Port Ecosystem Integration

Deployment: Web-based geospatial intelligence platform accessible on authority strategic planning dashboard, on executive dashboards, and embedded in masterplan presentations to government bodies and investors.

Why: A port does not exist in isolation. It is a node in a global shipping network, connected to hinterland (highways, rail corridors, inland waterways, air cargo), global trade lanes (Asia-Europe, Europe-Americas, Intra-Asia), competing ports, and supply chain networks. Authority executives need geospatial context to plan expansions, understand market position, identify competing threats, and optimize hinterland connectivity.

How: Spatial Map integrates GIS data, satellite imagery, AIS vessel tracking, OpenStreetMap infrastructure, demographic datasets, and trade flow data:

- Port campus in 3D geospatial context: Full port footprint (berths, yards, warehouses, gates, rail, fuel, dry docks) rendered in 3D and embedded in real-world geospatial context — surrounding roads, rail, waterways, terrain, vegetation at true scale.

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- Shipping lane visualization: Global shipping routes rendered in 3D above the Earth model. Port location shown relative to major East-West trade lanes, regional feeder routes, and Suez/Panama chokepoints. Critical for understanding port's position in global trade flows.
 - AIS vessel tracking integration: Real-time vessel positions for all ships >5000 GT globally. Filter by origin/destination to see which vessels serve the port. Analyze seasonal patterns and voyage routing to optimize berth schedules.
 - Hinterland connectivity mapping: Road network with traffic overlays (Google/TomTom integration). Rail lines with station positions relative to port gates. Inland waterway network (rivers, canals) for barges and feeder vessels. Highway/rail travel time isochrones (30 min, 60 min, 120 min) showing port's reach inland — which cities and industrial zones does this port serve?
 - Port catchment analysis: Circle map showing 30/60/120 minute reach from port. Overlay population density, industrial concentration, port-dependent cargo types (containers, breakbulk, project cargo, cars, minerals, grain). Quantify port's addressable market.
 - Competing port benchmarking: Overlay regional competitor ports (e.g., for Jebel Ali: KAEC, Ras Al Khair, Sohar) with their catchment areas, tariff structures (if available), and historical throughput trends. Identify which market segments each port dominates.
 - Environmental zones mapping: Port's EEZ (Exclusive Economic Zone), traffic separation schemes, piracy risk zones (if applicable), environmental protection areas (coral reefs, seagrass beds, mangroves). Important for operational planning and regulatory compliance.
 - Bathymetry & dredging depth contours: Seafloor depth map around port approaches and berths. Show current dredged depth vs. vessel draft requirements. Identify dredging maintenance needs and expansion dredging for larger vessel access (e.g., modern 24,000-TEU vessels need 15.5m draft; many regional ports only offer 14m).
 - Infrastructure development tracking: Planned highways, rail expansions, port expansions in the hinterland (e.g., NEOM rail connection to Saudi ports, Dubai–Abu Dhabi rail,

India's Dedicated Freight Corridor). Show how regional infrastructure evolution creates demand for port capacity.

- Trade corridor mapping: Major trade goods flowing through the port (containers, breakbulk, project cargo, autos, grain, oil, coal). Overlay production zones and consumption zones in the hinterland to visualize cargo origin/destination patterns.

Impact: Authority coordinates with government, regional partners, and private investors on a shared geospatial view. Expansion decisions backed by trade flow and connectivity data. Competing port threats identified early. Hinterland investment opportunities (inland container depots, distribution centres, manufacturing clusters) visible and monetizable.

Spatial Agent — Visitor & Driver Information Assistant

Deployment: AI avatar on touch kiosks at port main gates (vehicular and pedestrian), visitor information centres, and authority office lobbies.

Why: Ports are complex — multiple terminals, gates, operating companies, and procedures. Visiting truck drivers, cargo owners, and government inspectors need directions. An AI agent at a kiosk answers questions in real-time in multiple languages.

How: A truck driver approaches Spatial Agent kiosk at the main gate. Agent greets them: 'Welcome to Port Authority. How can I help?' Driver: 'I need Gate 3 for container XYZ123.' Agent responds: 'Gate 3 is in Terminal South, 500 meters, bear left at the intersection. You have a 15-minute wait currently. Need cargo documentation help?' Opens a menu with digital customs forms, reefer booking, or appointment rescheduling.

Impact: Gate operations move faster (drivers are pre-instructed). Reduced congestion at gate booths. Port authority reputation improved (better visitor experience).

Stakeholder 2: Smart Port Operations & IoT Command Centre

This is the operational nerve centre of the port. The Smart Operations team (port operations manager, vessel traffic coordinators, container yard supervisor, crane dispatcher, gate manager, safety/environmental officer) manages real-time flows using IoT sensor integration, live dashboards, and predictive analytics.

Deployment: Where Products Go, Why, How Used

Spatial Twin with Full IoT Integration — Real-Time Port Operations Dashboard

Deployment: Spatial Twin EXE integrated with IoT backend, running on the operations centre's main command wall (4-6 large displays or a unified 10m x 3m video wall).

Why: Port operations is a real-time coordination problem. Hundreds of decisions per day: Which berth should vessel X dock at? How do we stack incoming containers optimally to avoid re-handling? Should we dispatch Reach Stacker A or B to yard location? Which gate should the truck queue go to? Is Container Y's reefer functioning within spec? Which crane is running behind schedule? Without unified spatial + operational view, decision-makers are flying blind.

How: Operations team launches Spatial Twin on the command wall. It displays the port in photorealistic 3D with real-time IoT overlays continuously updating:

Vessel Traffic Management & Real-Time Ship Positioning

The Spatial Twin integrates AIS (Automatic Identification System) feeds from all vessels within port approach zone (pilot boarding ground, anchorage, berths). Each vessel appears as a 3D model with real-time position, heading, speed, and estimated time of arrival (ETA).

- Vessel positions updated every 10 seconds: Ships approaching port show position relative to pilot boarding point (typically 10-20 nm offshore). Ships in anchorage queue show berth assignment countdown. Ships at berth show discharge progress timeline.

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- Vessel traffic separation: System shows the fairway and recommended approach channel. If a vessel deviates (e.g., due to weather or mechanical issue), alert flags appear on screen.
 - Berth occupancy status: Each berth shows which vessel is occupying it, how much longer the vessel will be there, and which vessel is scheduled next. Operations manager can see if there are berth conflicts or idle berths.
 - Pilot & tugboat positions: Visual representation of pilot launch boat positions and tugboat positions relative to incoming vessels. Helps coordinate towage operations.
 - Vessel condition alerts: If a vessel's engine or navigational systems show anomalies (via vessel self-reporting or port authority monitoring), alert displayed on-screen. Helps port authority assess risk and safety.

Impact: Vessel traffic coordinators can respond immediately to schedule changes. If Vessel A's ETA slips by 6 hours, coordinator immediately reassigns the originally-planned berth to Vessel B, preventing costly idle berth time. Coordination time reduced from hours (via phone/email) to seconds (spatial visualization).

Container Tracking & Yard Positioning

The Spatial Twin displays real-time container positions in the yard using RFID/GPS tracking integrated with the port's terminal operating system (TOS). Each container appears on the 3D yard map with colour coding:

- Blue = Import containers waiting for gate-out. Red = Export containers waiting for vessel discharge. Green = Reefer containers (temperature-monitored). Yellow = Dangerous goods (hazardous cargo). Purple = Port-own empty containers.
- Container stack visualization: Containers stacked in the yard appear in 3D, showing exact bay/row/tier positions. Operators see which containers are 'blocking' (sitting on top of containers that need to move before them), helping identify re-handling inefficiencies.

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- Dwell time heatmap: Overlay colour gradient showing dwell time for each container — blue = recent arrival (low dwell), red = long dwell (at risk of gate demurrage charges). Helps identify backlog and prioritization issues.
 - Container size distribution: Show percentage of 20ft vs. 40ft vs. HC (high-cube) vs. OOG (out-of-gauge) containers by location. Helps crane dispatcher allocate spreader bar type needed.
 - Gate-out queue prediction: System predicts which containers will be requested for gate-out in the next 2-4 hours based on gate appointment reservations. Operators can pre-stage containers, reducing gate processing time.

Impact: Container yard utilization increases 15-20%. Re-handling (moving containers multiple times) decreases 25-30%. Gate processing time per truck reduced from 8-10 min to 4-5 min.

Crane Operations & Utilization Monitoring

Each quay crane (QC) and container gantry crane (RTG / RMG) is equipped with sensors measuring load, position, cycle time, and operational status. Spatial Twin renders each crane in real-time:

- Crane position & boom angle: Real-time crane position on the berth (Bay X) and boom angle/height. Helpful for coordinating vessel discharge and preventing boom collisions.
- Load visualization: Current load shown on screen (empty spreader, single container, double container, breakbulk). Operators see if cranes are productively utilized or idle.
- Cycle time tracking: Time from last pickup to current position. If cycle time is abnormally slow (20+ seconds per move when target is 12-15 seconds), alert displayed. Indicates operator fatigue, mechanical issue, or congestion.
- Moves per hour metric: System calculates crane productivity (moves/hour) in real-time. If a crane is below target (e.g., 20 moves/hour instead of 30), supervisor can investigate (operator issue? Equipment maintenance?). This drives crane efficiency improvements.
- Predictive maintenance alerts: Crane sensors monitor motor temperature, wire rope tension, and hydraulic pressure. If parameters drift outside normal range, system alerts

maintenance team before failure. Prevents costly crane downtime (USD 50,000+ per day).

Impact: Crane utilization increases 20-30%. Preventive maintenance prevents 60-70% of unplanned breakdowns. Vessel discharge time reduces 15-20%, lowering vessel demurrage cost.

Gate Operations & Truck Queue Management

Port gates are the throughput bottleneck. Each gate has OCR (optical character recognition) readers scanning container numbers, truck drivers, and cargo seals. Spatial Twin visualizes real-time gate operations:

- Gate queue visualization: Visual representation of truck queue at each gate (Gate 1, Gate 2, etc.). Queue length shown in meters or number of trucks. If queue is growing, system alerts gate manager to open additional lanes or reroute trucks to less-congested gates.
- Average gate processing time: Real-time average time per truck at each gate (document check, container seal verification, weight check, destination confirmation). If processing time exceeds 5 minutes, alert displayed — indicates slowdown (short-staff? System issue?).
- OCR scanning success rate: Percentage of containers scanned successfully on first attempt. If OCR is failing (e.g., damaged container numbers), operator is alerted to manual entry mode. Helps diagnose scanning hardware issues.
- Gate appointment vs. walk-in ratio: System tracks scheduled vs. unscheduled trucks. If walk-in ratio is high (>30%), gate congestion will result — system proactively recommends appointment slots to truck drivers via SMS/app.
- Peak hour forecasting: Based on appointment database and historical patterns, system predicts gate load in the next 2-4 hours. If peak is forecast, gate manager can pre-authorize overtime staff or open additional gates.

Impact: Gate processing time reduced 20-30% (from 6-8 min average to 4-5 min). Truck queue length reduced 40-50%, improving driver experience and reducing port congestion. Gate revenue (processing fees) increases due to higher throughput.

Reefer Container Temperature & Environmental Monitoring

Reefer (refrigerated) containers carrying perishables (fruit, fish, meat, dairy, pharmaceuticals) require constant temperature/humidity monitoring. IoT sensors on each reefer container transmit data every 30 seconds. Spatial Twin displays:

- Reefer status by location: On the yard map, each reefer container is colour-coded: Green = within spec (e.g., $-18^{\circ}\text{C} \pm 2^{\circ}\text{C}$ for frozen goods), Yellow = approaching limit, Red = out-of-spec. Helps operators identify at-risk containers immediately.
- Temperature trend graph: For any selected reefer, system shows temperature history over past 24 hours. If a container's temperature drifted out of spec at 2 AM (e.g., power failure), operator can see exactly when the problem occurred and take corrective action (reseal the reefer plug, move to backup power circuit).
- Reefer port connection status: Reefers plugged into the port's shore power have green status. Reefers awaiting connection (from vessel to port reefer terminals) show yellow. Disconnected reefers (vessel-to-truck) rely on internal diesel power — operator must ensure they're not sitting idle (fuel depletion + temperature loss risk).
- Cargo loss prediction: System calculates probability of cargo loss (spoilage) based on temperature excursion history and duration. If a container has been out-of-spec for >4 hours, probability of loss >70%, and it's high-value cargo (e.g., seafood worth USD 50,000), alert escalates to terminal operator and cargo owner.
- Reefer maintenance scheduling: System tracks reefer unit runtime and predicts maintenance intervals (compressor servicing every 10,000 hours). Helps avoid mid-season equipment failures.

Impact: Reefer cargo loss reduced 35-50% (from typical 2-5% loss rate to <1%). Cargo owner satisfaction increases, driving repeat business. Port reputation for reefer handling excellence drives volume growth from perishables traders.

Environmental & Safety Monitoring

Ports operate in environmentally sensitive areas and are subject to air quality, water quality, and noise regulations. Spatial Twin integrates environmental sensors:

- Air quality (PM2.5, PM10, NO2, SO2): Sensors stationed around the port perimeter (especially near residential areas) measure air quality. Real-time display on Spatial Twin shows which zones are within safe limits. Important for ports with bulk cargo terminals (coal, grain, iron ore) that generate dust. If PM2.5 exceeds 150 $\mu\text{g}/\text{m}^3$, operations manager may need to halt cargo operations temporarily to avoid community complaints/regulatory action.
- Water quality in port basin: pH, salinity, dissolved oxygen, oil sheen detection. If water quality degrades (e.g., oil spill detected by satellite or floating skimmers), alert displayed. Helps port authority respond quickly to environmental incidents.
- Noise level monitoring: Sensors measure noise from crane operations, cargo handling, and truck movements. If noise exceeds thresholds near residential areas, system alerts operations manager. Can be used to shift noisiest operations away from night hours.
- ISPS Code compliance tracking: Port Security Level (1/2/3) status, security perimeter verification, unauthorized access attempts, CCTV coverage status. Real-time display ensures port maintains maritime security regulations (ISPS = International Ship and Port Facility Security Code).

Impact: Port operates within environmental compliance, avoiding regulatory fines and community objections. Security incidents reduced through real-time monitoring. Port authority reputation enhanced.

Weather & Tide Integration

Weather and tide conditions critically impact port operations. Spatial Twin integrates weather forecasts and real-time tide data:

- Wind speed & direction: Real-time wind overlay on Spatial Twin. Critical for crane safety — most port cranes have a 65 km/h wind speed limit (above which boom might experience oscillation). If wind is forecast to exceed 60 km/h in next 2 hours, system alerts crane dispatcher to slow crane operations or halt.
- Wave height at berths: Real-time wave height measured by buoys or forecast from meteorological data. High waves (>2-3m) make ship-to-ship transfers risky and slow cargo operations. System flags when vessel operations should be suspended.
- Tide level prediction: System shows current tide level and forecast for next 12-24 hours. Critical for vessel draft clearance (e.g., a 24,000-TEU vessel drawing 15m needs at least 15.5m water depth; at low tide, a port with 15.2m dredged depth cannot accommodate the vessel). Helps port authority schedule vessel arrivals around favorable tides.
- Visibility (fog/rain): If fog develops (reducing visibility), operations manager may need to reduce crane operations speed or halt ship movements in approach channels until visibility improves.

Impact: Vessel scheduling optimized around weather/tide windows, reducing delays. Crane safety incidents prevented through wind monitoring. Vessel delays due to weather reduced 15-20%.

Dynamic Resource Allocation & Optimization

Spatial Twin integrates with optimization algorithms that dynamically allocate yard equipment (reach stackers, terminal tractors, forklifts) based on real-time demand:

- Vessel discharge plan integration: When a vessel arrives and berthing procedure begins, port systems receive the vessel's discharge plan (which containers are discharging in which order from which holds). Spatial Twin's optimization engine allocates yard

equipment to receive containers at the optimal location, minimizing transportation distance and congestion.

- Truck appointment system: System matches truck appointments with optimal gate and lane, minimizing average wait time. If gates are becoming congested, system can suggest earlier/later appointment times to drivers via SMS, load-balancing the gate queue.
- Rail loading schedule: For exports moving via rail, system schedules rail loading windows to match container availability in the yard. Avoids scenarios where the rail wagon departs with empty capacity.
- Equipment utilization dashboard: Real-time view of which reach stackers are idle, which are in-transit, which are actively loading/unloading. Helps supervisor dispatch equipment efficiently, avoiding overload of some machines while others sit idle.

Impact: Yard throughput increases 20-25%. Equipment utilization increases from 60-70% to 80-85%. Waiting time for trucks/containers reduced significantly.

Facility Maintenance & Structural Health Monitoring

Quay walls, berth pavements, fender systems, cranes, and other port infrastructure require maintenance. IoT sensors and predictive analytics help prevent failures:

- Quay wall structural sensors: Sensors embedded in quay walls measure settlement, tilt, and stress. If a sensor shows unusual movement (e.g., 5mm settlement in a week instead of normal 0.5mm/year), system alerts maintenance team to inspect. Prevents catastrophic quay collapse.
- Fender condition monitoring: Berth fenders absorb impact from docking vessels. Worn fenders reduce shock absorption, risking ship damage. Sensors measure fender wear. When fenders reach 80% wear, system schedules replacement before failure.
- Pavement management: Temperature sensors and crack detection cameras monitor port pavements (for truck traffic). System predicts which areas will fail in next 6-12 months, allowing planned maintenance rather than emergency repairs.

- Electrical & lighting infrastructure: Smart meters and sensors on the port's electrical distribution, lighting, and water/waste systems. Predicts failures, guides maintenance scheduling.

Impact: Unplanned downtime reduced 40-50%. Maintenance costs reduced 20-30% through predictive scheduling. Port availability increases from 95-97% to 98-99%.

Key Metrics: Smart Port Operations Impact Summary

| Metric | Before | After | Improvement |
|------------------------------|---------------------|---------------------|-------------|
| Vessel Turnaround Time | 3-5 days | 2-3 days | 30-40% |
| Container Yard Throughput | 500-600 TEU/day | 650-750 TEU/day | 25-30% |
| Gate Processing Time | 6-8 minutes | 4-5 minutes | 35-40% |
| Crane Productivity | 20-25 moves/hour | 28-35 moves/hour | 30-40% |
| Reefer Cargo Loss Rate | 2-5% | <1% | 70-80% |
| Gate Congestion Incidents | 4-6 per day | 0-1 per day | 85-90% |
| Safety Incidents (port-wide) | 3-5 per month | 1-2 per month | 60-70% |
| Unplanned Equipment Downtime | 2-3 incidents/month | 0-1 incidents/month | 70-80% |

Stakeholder 3: Shipyard & Naval Architecture

Shipyards design and build vessels. PROPVR enables collaborative design review across naval architects, classification societies, shipowners, and equipment suppliers.

Key Products

- Spatial Twin: Walk through ship engine room, cargo holds, bridge. Identify design flaws before construction.
- Spatial Cave: Multi-stakeholder design review sessions. All stakeholders (architects, shipowner, classification society, flag state) walk the virtual ship together.
- Spatial Table: General arrangement planning. Optimize compartment layout, emergency routes, crew movement.
- Spatial Lens (AR): On-dock construction overlay. Verify structural positioning matches CAD as steel is welded.
- Spatial Tour (VR): Individual immersive design reviews. Remote stakeholders (equipment suppliers in Europe, shipowner in Asia) participate without traveling.

Impact: Design approval cycle compressed from 6-8 weeks to 1-2 weeks. Rework due to coordination gaps reduced 50-60%.

Stakeholder 4: Cruise Line Sales & Marketing

Cruise lines sell cabins and experiences. PROPVR enables immersive pre-purchase exploration that converts bookings.

Key Products

- Spatial Twin: Walk through cabins (suite, balcony, oceanview, inside), public areas (dining, pool, theatre, spa). Experience the ship before booking.
- Spatial Touch: Zero-latency cabin tours in booking offices and travel agency flagship stores. Sales staff show premium cabins on large screen.
- Spatial Cave: Immersive cruise booking expos (Seatrade Cruise Global, CruiseWorld). Visitors experience the ship in 270° display — showstopping booth attraction.
- Spatial Stream: Web-embedded cabin browsing on cruise line website. Passengers explore cabins inline during booking, zero download.
- Spatial Drive: Group sales presentations. Account managers pitch corporate charters using interactive Spatial Drive presentations.
- Spatial Agent: Virtual cruise consultant on website. Answers cabin questions 24/7 in multiple languages.
- Gamification: Virtual scavenger hunt through the ship. Passengers explore ship, collect points, earn discount codes.

Impact: Premium cabin upsell conversion increases 40-50%. Pre-booking exploration reduces cancellation rate 15-20%.

Stakeholder 5: Mega-Yacht & Luxury Vessel Broker

Ultra-high-net-worth clients purchase mega-yachts (USD 50M-500M+). Brokers need immersive experiences for geographically dispersed buyers.

Key Products

- Spatial Twin: Walk through 80m+ superyacht master suite, sky lounge, beach club, engine room. Experience the USD 200M yacht without traveling to Monaco.
- Spatial Touch: Private showroom experience. Ultra-high-resolution, zero-latency on 85-inch screen in Monaco, Dubai, Fort Lauderdale offices.
- Spatial Cave: Exclusive yacht showcases at boat shows (Monaco Yacht Show, Dubai International Boat Show).
- Spatial Tour (VR): Remote clients in Asia/Americas experience yacht via VR from home/office.
- Day/night simulation: Show yacht at sunset in Mediterranean, under stars in Caribbean anchorage.

Impact: Sales cycle compressed 6-12 months. Buyer confidence increases; deals close faster.

Stakeholder 6: Ship Owner & Fleet Manager

Ship owners manage fleets of tens to hundreds of vessels. Real-time visibility drives operational efficiency.

Key Products

- Spatial World: Fleet dashboard. All vessels shown with real-time AIS positions, operational status, revenue metrics, maintenance schedules.
- Spatial Twin: Vessel condition assessment. Virtual surveys before dry dock to evaluate hull, engine room, cargo handling systems.
- Spatial Map: Vessel tracking, shipping route visualization, port rotation planning, trade corridor intelligence.
- Predictive maintenance: IoT sensors on engine, hull, ballast systems. Spatial Twin integrates sensor data, predicts maintenance needs.

Impact: Fleet utilization optimized 10-15%. Maintenance planning efficiency improves 30-40%. Vessel downtime reduced.

Stakeholder 7: Crew Training & Safety

Maritime crew training must be immersive, hands-on, and compliance-focused (STCW). PROPVR scales training delivery.

Key Products

- Spatial Twin: Safety drill simulation. Crew walks through abandon ship, man overboard, fire-fighting procedures. Immersive training drives better recall.
- Spatial Cave: Training centres deploy immersive engine room, bridge, cargo handling training for multiple crews simultaneously.
- Spatial Tour (VR): Individual officer certification training. Officers certify on new vessel types via VR before joining live vessel.
- Spatial Lens (AR): On-board/on-dock maintenance procedures. Overlay maintenance steps on actual equipment.
- Spatial Agent: AI training assessment. Quiz crew on safety procedures, certify competency.
- Gamification: Crew earn badges for training completion, scored on speed and accuracy.

Impact: Training time-to-competency reduced 30-40%. Safety incident rates decrease 25-35%. Crew satisfaction and retention improve.

Stakeholder 8: Maritime Trade Shows & Industry Events

Major maritime events (Posidonia Athens, SMM Hamburg, Seatrade Cruise Global, Dubai Maritime Summit) are marketing stages for PROPVR.

Key Products

- Spatial Cave: Trade show booth centerpiece. Immersive 270° display of ship/port attracts visitors, generates leads.
- Spatial Holo: Eye-catching holographic ship/port model display in exhibition booth.
- Spatial Touch: Interactive demo stations. Fast, impressive demos on 65-inch screen.
- Spatial Tour (VR): One-on-one immersive experiences at booth. Visitors try VR headset.
- Spatial Drive: Structured sales presentations at meetings during events.

Impact: Trade show ROI increases 30-50% (higher-quality leads). Vendor relationships strengthened. Brand presence elevated.

Stakeholder 9: Maritime Investor & Sovereign Wealth Fund

Sovereign wealth funds evaluate port/maritime infrastructure investments (USD 10-50B+). Decision-making requires geospatial intelligence and immersive visualization.

Key Products

- Spatial Cave: Investment presentations. Port authority pitches expansion to investors in immersive boardroom.
- Spatial World: Portfolio overview. Investors see operational metrics and financial performance across multiple assets.
- Spatial Map: Geospatial intelligence. Hinterland GDP, trade corridor volumes, competing port capacity, shipping lane traffic, AIS vessel flows.
- Spatial Drive: Structured investment pitches and roadshows.

Impact: Investment decision-making accelerated. Fund commits capital 3-6 months faster when visualization de-risks the decision.

Geospatial Intelligence Deep Dive: Spatial Map

Spatial Map is PROPVR's geospatial intelligence platform. For maritime, it integrates shipping lanes, AIS vessel tracking, port catchment analysis, hinterland connectivity, trade corridors, environmental zones, bathymetry, and competing port analysis.

Core Capabilities

- Global shipping lane mapping: Container, bulk, tanker routes. Routes colored by traffic volume.
- AIS vessel tracking: Real-time positions of all vessels >5,000 GT globally. Filter by type, origin, destination.
- Port catchment analysis: 30/60/120-minute inland accessibility. Overlay population, industry, cargo types.
- Trade corridor intelligence: Major trade flows (Asia-Europe, intra-Asia, North Africa-Asia) visualized as flow ribbons.
- Environmental zones: EEZ boundaries, traffic separation schemes, piracy zones, marine protected areas.
- Bathymetry & dredging: Seafloor depth maps, current dredged depth, planned dredging for larger vessel access.
- Competitor port benchmarking: Regional ports overlaid with catchment, capacity, tariffs, market share.

Impact: Authority and investors make data-backed strategic decisions. Expansion plans optimized for market demand and competitive positioning.

The Container Journey: Spatial OS Touchpoints

To illustrate how PROPVR products integrate, we trace container XYZ123 (40ft HC, electronics, Shanghai to Dubai) through the port:

- Vessel approach: Spatial Map shows vessel MV GreatWall approaching. Spatial World shows vessel on command wall, berth assignment.
- Berth arrival: Vessel berthed at Berth 5. Spatial Twin shows crane dispatch. Container is Hatch 3, Bay 24, Row A, Tier 2.
- Crane discharge: Quay crane operator receives discharge plan via Spatial Twin. Crane picks container, discharges. Spatial Twin shows real-time crane position and cycle time.
- Yard transport: Terminal tractor transports container to yard Bay 45, Row 2, Tier 1. RFID/GPS updates position every 30 seconds.
- Yard dwell: Container sits 18 hours. Spatial World shows 'Import, awaiting gate appointment.' Dwell time heatmap indicates mid-dwell status.
- Gate appointment: Consignee books gate slot via Spatial Agent chatbot. System assigns Gate 2, 3:00 PM. Spatial World shows gate queue (4 trucks, 45 min wait).
- Gate preparation: Reach stacker dispatched via dynamic allocation. Spatial Twin shows reach stacker en route to container location.
- Gate processing: Container arrives at Gate 2. OCR scans number. Processing time: 4 minutes (document, seal, system exit). Container clears gate 3:48 PM.
- Exit: Container departs port in truck. Spatial Map shows truck route (GPS) to Dubai distribution centre. Delivery next day.

Throughout, PROPVR products provide real-time visibility to port operators, terminal staff, consignees, and managers.

ROI Analysis by Stakeholder

| Stakeholder | Primary Benefit | Annual Impact (USD) | Payback |
|-------------------|-------------------------------------|---------------------|----------|
| Port Authority | Faster approvals, reduced rework | 2-5M | 2-3 yrs |
| Smart Operations | Turnaround, throughput, reefer loss | 3-8M | 1-2 yrs |
| Shipyard | Design cycle, rework avoidance | 5-10M | 1-2 yrs |
| Cruise Line | Cabin sales conversion uplift | 10-20M | 0.5-1 yr |
| Mega-Yacht Broker | Sales cycle acceleration | 2-5M | 1-2 yrs |
| Ship Owner | Fleet utilization, maintenance | 1-3M | 2-3 yrs |
| Training Centre | Crew throughput, safety | 0.5-1M | 2-3 yrs |
| Investor | Better decision-making | 2-10B portfolio | 1-2 yrs |

Implementation Roadmap: 30-Month Deployment

Phase 1: Foundation (Months 1-6)

- LiDAR scan of port campus. CAD integration for ship interiors.
- Spatial Twin development: port model, vessel models, cruise ship interiors.
- GIS/Spatial Map setup: geospatial data, shipping lanes, AIS integration.
- Team training. Initial Spatial Cave deployment.

Phase 2: Smart Operations (Months 7-12)

- IoT sensor integration: container tracking, crane sensors, vessel AIS, weather/tide feeds.
- Spatial Twin backend: real-time port operations dashboard on command wall.
- Spatial World: operations portfolio, fleet tracking.
- Spatial Agent: gate kiosk AI.

Phase 3: Sales & Marketing (Months 13-18)

- Cruise ship interior Spatial Twin: full cabin, public areas, VR/Stream.
- Spatial Drive: sales presentations.
- Spatial Touch: booking offices, travel agencies.
- Spatial Holo: yacht/ship models.

Phase 4: Training & Events (Months 19-24)

- Crew training platform (Spatial Twin + Tour).
- Trade show presence: Spatial Cave booth, demos.
- Spatial Lens (AR): on-dock, on-board, training.

Phase 5: Optimization & Scaling (Months 25-30)

- Predictive maintenance: ML for equipment failure prediction.
- Spatial Table: port planning centres, shipyards.
- Advanced Spatial Map: trade intelligence, hinterland optimization.
- Expansion to additional ports and shipyards.

Reference Ports & Facilities

- Jebel Ali Port (DP World, Dubai): 15M TEU/year, 67 berths.
- King Abdullah Economic City Port (KAEC, Saudi Arabia): USD 27B megaproject, 20M+ TEU/year future capacity.
- JNPT Nhava Sheva (Mumbai, India): 6M TEU/year, South Asia gateway.
- Mawani Ports (Saudi Arabia): Red Sea, Arabian Gulf, Indian Ocean network.
- Ras Al Khair Industrial Port (Saudi Arabia): bulk, container, petrochemical.
- Dammam Port (Saudi Arabia): Arabian Gulf regional port.
- Sohar Port (Oman): container, general cargo, bulk, breakbulk.
- NEOM industrial port (Saudi Arabia): future mega-port.

Get Started

PROPVR delivers the complete Spatial OS platform — from photorealistic digital twins and gamified walkthroughs to holographic displays, immersive rooms, AI assistants, and pixel-streamed web experiences. One content investment powers every product across every channel.

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