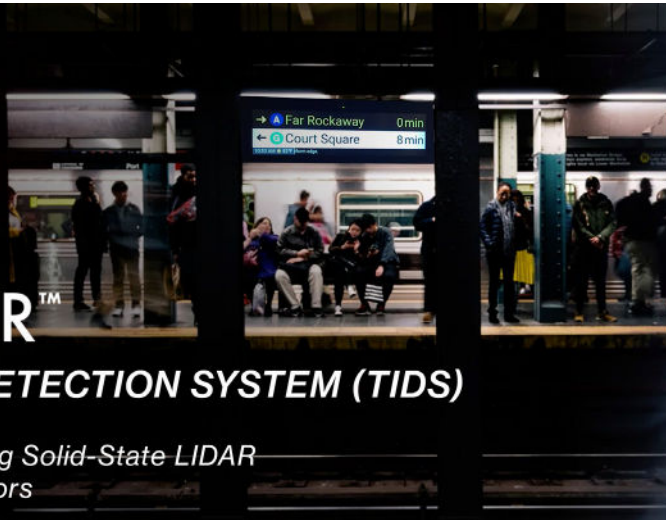


piiper®

STANDCLEAR™ TRACK INTRUSION DETECTION SYSTEM (TIDS)

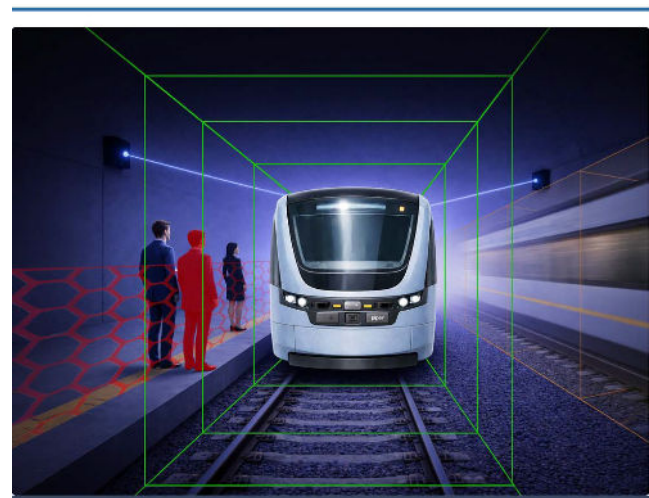
Track Intrusion Detection using Solid-State LIDAR
and Time of Flight (ToF) Sensors



THE CHALLENGE

Every day, passengers at rail and transit stations face a risk that is difficult to eliminate through signage, barriers, or staff presence alone — the risk of falling, being pushed, or walking onto the track. For train operators, the challenge is equally serious: by the time a hazard in the fouling area is visible from the cab, stopping distance is often insufficient.

The risk extends beyond the moment of intrusion. Passengers leaning toward the track, erratic movements on a crowded platform, or sudden crowd displacement near the platform edge are all precursors to serious incidents — and traditional systems cannot detect them. CCTV monitored by staff depends on sustained human attention. Basic proximity sensors detect only what has already entered the fouling area. StandClear™ takes a different approach: a safety-certifiable geometric foundation combined with AI-enhanced behavioral intelligence that recognizes threats before they become intrusions.



StandClear™ in operation — sensor fields detecting platform encroachment in real-time.

HOW STANDCLEAR™ WORKS

TrackSight™ LiDAR

Platform-end mounted · detects a 1m³ object at 100m

Piper's patented solid-state TrackSight™ LiDAR sensors are positioned at the ends of platforms, facing down the tunnels and along station tracks. Not susceptible to degradation from headlights, darkness, or other visual spectrum interferences.

Time of Flight (ToF) Cameras

Ceiling-mounted · up to 16m — detects between berthed trains

Piper's proprietary ToF cameras measure the distance to objects by calculating the round-trip time of reflected light signals. Ceiling-mounted above platform edges, they are fully operational in low-light and no-light conditions, eliminate sun glare, and can see between berthed trains.

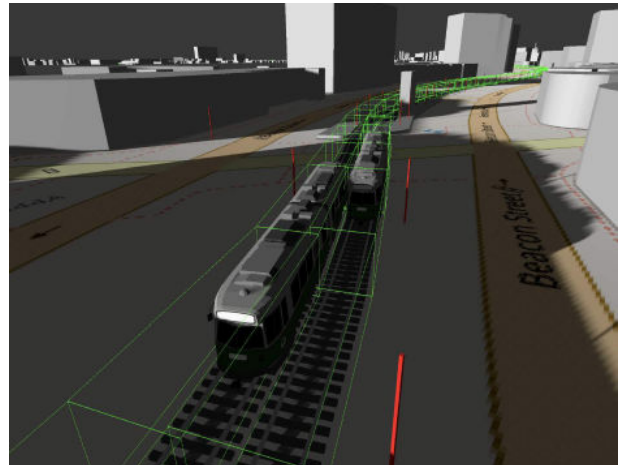


VIRTUAL TUNNELS

Digital clearance envelope · geometry-driven alerting · no image processing latency

Both sensor systems operate within Piper's proprietary Virtual Tunnel framework — a digital model of the track's dynamic clearance envelope built from a survey of the station geometry. Virtual Tunnels are constructed as strings of polyhedrons along the centerline spline of the track, calibrated to the operator's requirements. They define precisely where intrusion alerts should and should not be generated, ensuring the system responds only to genuine hazards within the fouling area — with no latency from image processing.

The system operates with a duty cycle of 100 milliseconds, with any latency confined to the communications channel — not the detection logic itself. Detection performance is consistent and predictable from commissioning day.

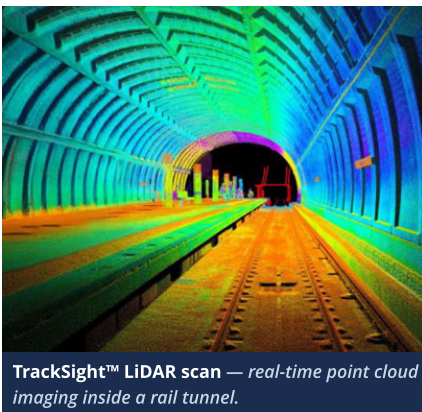


DETECTION SCENARIOS

StandClear™ detects and classifies the full range of guideway intrusion and pre-intrusion scenarios at passenger stations:

<p>Platform edge approach Passengers getting too close to or crossing the platform edge.</p>	<p>Platform falls Accidental falls from the platform onto the track, detected immediately.</p>
<p>Deliberate intrusions Malicious or deliberate track intrusions triggering immediate operator alert.</p>	<p>Object detection Luggage, equipment, and debris left in the fouling area — flagged with sufficient stopping distance.</p>
<p>Tunnel entrance Intrusions into tunnel entrances from platform edges — covered by TrackSight™ LiDAR.</p>	<p>Animate/inanimate discrimination The system reliably distinguishes people and animals from objects, enabling proportionate alert responses.</p>
<p>Pre-intrusion behaviors Passengers leaning toward the ROW, erratic movements, and unusual crowd movements near the platform edge — detected before an intrusion occurs.</p>	<p>Crowd dynamics Overcrowding and sudden displacement of people on the platform, detected under both low and high passenger density conditions.</p>

TWO-LAYER ARCHITECTURE (DETERMINISTIC CORE + AI/ML ENHANCEMENT LAYER)



TrackSight™ LiDAR scan — real-time point cloud imaging inside a rail tunnel.

StandClear™ combines a deterministic geometric foundation with AI-enhanced behavioral intelligence. At its core, the system compares real-time sensor data against the Virtual Tunnel geometric model — a fixed boundary check that is inherently auditable, SIL-4 safety certifiable, and consistent from commissioning day with no training period. Built on top of this foundation,

StandClear™'s machine learning layer extends detection beyond boundary breaches to recognize and classify pre-intrusion behaviors: passengers leaning toward the ROW, erratic movements, crowd displacement, and unusual platform density patterns. Event classification drives the alert response — determining the appropriate notification level, contextual information, and escalation path delivered to train operators, station staff, and control center personnel. The system continuously improves its classification accuracy based on operator feedback. The result is a system that is both safety-certifiable at its core and adaptive in its intelligence.

ALERTS AND INTEGRATION

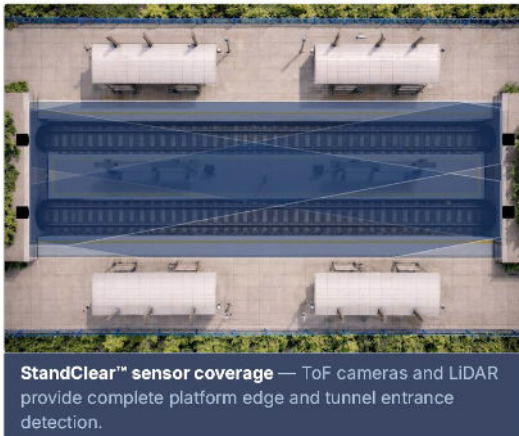
When StandClear™ detects a hazard, it communicates through multiple channels simultaneously to ensure the appropriate parties are notified with sufficient time to act:

<p>TRAIN OPERATOR</p> <p>Direct alerts to the Piper Vehicle Operator Display (VOD) in the approaching train cab.</p>	<p>RIGHT OF WAY</p> <p>Visible signals and strobes from the right of way, visible to the train operator on approach.</p>
<p>TRACK LIGHTING</p> <p>Integration with track lighting systems for platform-wide visual warnings.</p>	<p>PASSENGER ALERTS</p> <p>Targeted audible warnings and LED light pipe alerts to passengers in encroaching areas.</p>
<p>TRAIN CONTROL</p> <p>Communication link into the train control system for automated responses.</p>	<p>DATA & ANALYTICS</p> <p>All video and telemetric data stored securely for forensic analysis and incident review.</p>



Piper Vehicle Operator Display (VOD) —
obstruction detected alert in the train cab.

INSTALLATION AND INTEGRATION



StandClear™ is designed for straightforward installation into existing station infrastructure. ToF sensors mount on ceilings above platform edges with standard wayside power — typically 110 volts or 277 VAC. LiDAR sensors are positioned at platform ends with an effective detection range of 100 meters for a 1m³ object. A station survey is required to build the Virtual Tunnel database prior to commissioning.

Communication between sensor devices and the operator network is facilitated via Ethernet, LTE, or Wi-Fi, with an option for an on-premises secure closed copper connection. An API for OCC integration is also included. Piper is an experienced systems integrator and can adapt the installation to the specific layout and existing infrastructure of each station.

STANDALONE OR INTEGRATED

The system can operate as a standalone solution or integrate directly into existing train control and station management systems.

REMOTE MANAGEMENT

A cloud-based systems administration platform monitors all components, with Over-the-Air (OTA) remote management for maintenance and updates.

PERFORMANCE AND RELIABILITY

All-Condition Operation

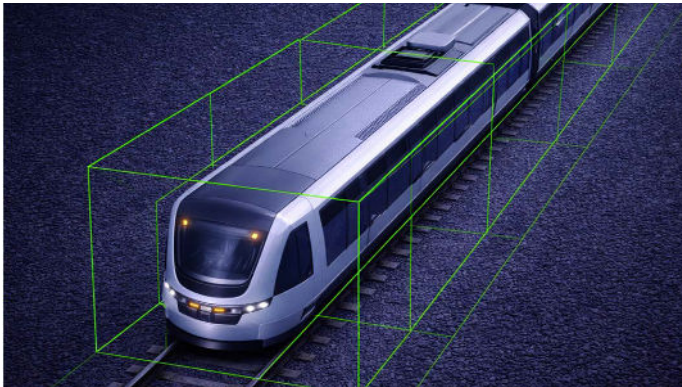
TrackSight™ LiDAR is inherently immune to headlights, darkness, and visual spectrum interference, and ceiling-mounted ToF sensors eliminate sun glare entirely by virtue of their downward-facing installation geometry. For conditions where environmental factors affect optical performance — heavy fog, tunnel dust, or precipitation — Piper has developed proprietary software mitigation methods that maintain detection reliability.

Proven Track Record

No anomalous failures have been reported across 600 railbound vehicles operating for 3.5 years in the Northeast Corridor. Piper's FRACAS process — Failure Reporting, Analysis, and Corrective Action System — ensures ongoing maintenance tracking and systematic extraction of performance data across all deployed installations.

BENEFITS OF STANDCLEAR™

<p>Safety-certifiable foundation</p> <p>The geometric boundary check at the core of StandClear™ is inherently auditable and consistent from commissioning day. Piper's TrackSight™ LiDAR is SIL-4 safety certifiable and in the process of being certified.</p>	<p>AI-enhanced behavioral detection</p> <p>Machine learning extends detection beyond boundary breaches to classify pre-intrusion behaviors: passengers leaning toward the ROW, erratic movements, and crowd displacement — before an incident occurs.</p>
<p>Operational in all conditions</p> <p>LiDAR operates on reflected laser pulses — immune to headlights, darkness, and visual spectrum interference. ToF sensors eliminate sun glare by design. Proprietary software mitigates fog, dust, and precipitation effects.</p>	<p>Comprehensive platform coverage</p> <p>Combined ToF and LiDAR coverage addresses the full platform edge, fouling area, and tunnel entrance with no detection gaps. ToF sensors also see between berthed trains.</p>
<p>Contextual, classified alerting</p> <p>Event classification drives alert response — delivering the right notification level, contextual information, and escalation path to train operators, station staff, and control center personnel simultaneously.</p>	<p>Zero nuisance alarms by design</p> <p>Geometry-only boundary detection at the safety layer means alerts are generated only when the fouling area is genuinely breached — never from pattern mismatches or unfamiliar objects.</p>
<p>Animate and inanimate object discrimination</p> <p>Reliably distinguishes people and animals from objects, enabling appropriate and proportionate alert responses, even in low-light conditions.</p>	<p>Easy to integrate</p> <p>Compatible with existing station power, communications infrastructure, and train control systems. API for OCC integration included. Real-time train positioning data interface supported.</p>
<p>Meets stringent rail standards</p> <p>Compliant with CENELEC, AREMA, and IEEE standards. Piper's LiDAR is AEC-Q100 certified for transit and automotive applications.</p>	<p>Remote management</p> <p>OTA software and GUI workstation for health monitoring and updates. FRACAS reporting facilitates ongoing maintenance tracking across all installed locations.</p>



STANDARDS & CERTIFICATIONS

<p>CENELEC SIL-4</p> <p>System components certified or in the process of achieving Safety Integrity Level 4 — the highest standard in the rail industry.</p>	<p>AEC-Q100</p> <p>Piper's LiDAR sensors are AEC-Q100 certified for use in transit and automotive applications.</p>	<p>AREMA / IEEE</p> <p>Compliant with AREMA and IEEE standards for railway signaling and safety systems.</p>
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Part of the Piper Platform

StandClear™ uses the same **TrackSight™ LiDAR** hardware deployed across Piper's Vital Train Positioning platform — proven in revenue service at Amtrak, MTA New York City, and other major US operators. No anomalous failures reported across **600 railbound vehicles operating for 3.5 years** in the Northeast Corridor. The same sensing technology that keeps trains positioned with centimeter accuracy keeps passengers safe at platform edges.