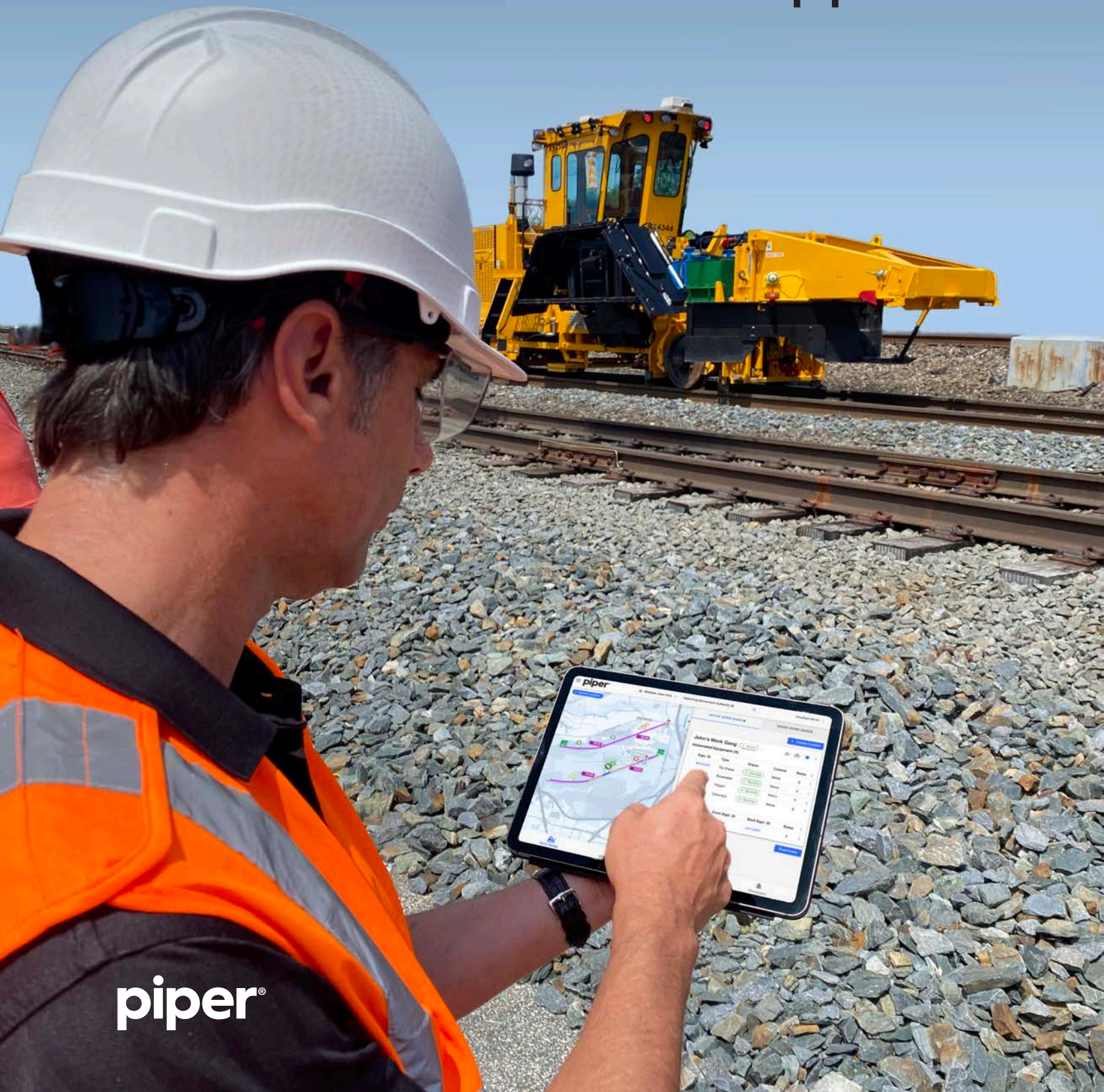
DYNAMIC WORK ZONE AWARENESS & ROADWAY WORKER PROTECTION (RWP)

SECURETRACK™

by piper



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INTRODUCTION

Piper's SecureTrack solution comprises Work Zone Awareness and Management, Roadway Worker Protection (RWP), and a Limits Compliance and Collision Avoidance System (LCCAS). The solution improves safety for train operators and track workers during construction or maintenance activities on the railway. It leverages existing infrastructure from train positioning systems and adds new features specifically for work zone protection. Smart sensors, wearables, and a robust work zone management platform are used to localize trains, MoW vehicles and track workers within the territory or yards and communicate location information to approaching trains, employees-in-charge, and the rail control center.

Piper's advanced **Limits Compliance and Collision Avoidance System (LCCAS)** uses a modular vehicle-centric safety system with multiple sensors to address challenges, including collision avoidance, obstacle detection, limits compliance, collision detection, and event recording. **Roadway Worker Protection (RWP)** is an advanced wearable solution that leverages LCCAS to detect and track workers fouling tracks in real-time and alerts train operators to their presence.

Piper has expanded its LCCAS to incorporate advanced **Work Zone Awareness** and management. A new Employee-in-Charge (EIC) application that integrates with Rail Control Centers (RCC) allows for remote, real-time management of Maintenance of Way (MoW) fleets with improved safety and reduced cost. Using their ruggedized tablets, EICs can use the Fleet Manager App (FMA) to easily create work gangs, view and assign vehicles, set work territory limits, create consists, apply rules, and view live telemetry. Dispatchers are notified in real-time and can view and approve requests and monitor multiple work gangs. An intuitive Vehicle Operator Display (VOD) provides feedback from the sensors locally to generate audio/visual operator alerts. Operators can be notified of overspeeding, distance to and from established work zones for limits compliance, and proximity to nearby vehicles and obstacles.

BENEFITS OF SECURETRACK

SecureTrack offers significant advantages for both safety and efficiency in rail and transit systems:

- **Enhanced Safety:** Real-time equipment positioning allows train operators to adjust speed and maintain a safe distance when approaching or within work zones. This significantly reduces the risk of accidents involving track workers and other vehicles.
- **Improved Communication:** The system facilitates clear communication between train operators and work crews. Operators understand worker presence, while workers receive alerts about approaching trains.
- **Remote Work Zone Management:** Work zones can be established and modified remotely through the platform, eliminating the need for manual setup and reducing potential errors.
- **Roadway Worker Protection (RWP):** This solution goes beyond traditional RWP by providing real-time tracking and improved communication. It complements existing safety protocols by adding another layer of protection.
- **Increased Worker Accountability:** The system confirms worker location at the end of shifts, ensuring everyone is clear before authorizing vehicle movement in the area.
- **Efficiency Gains:** Clearer communication and improved awareness can lead to smoother operations and reduced delays.
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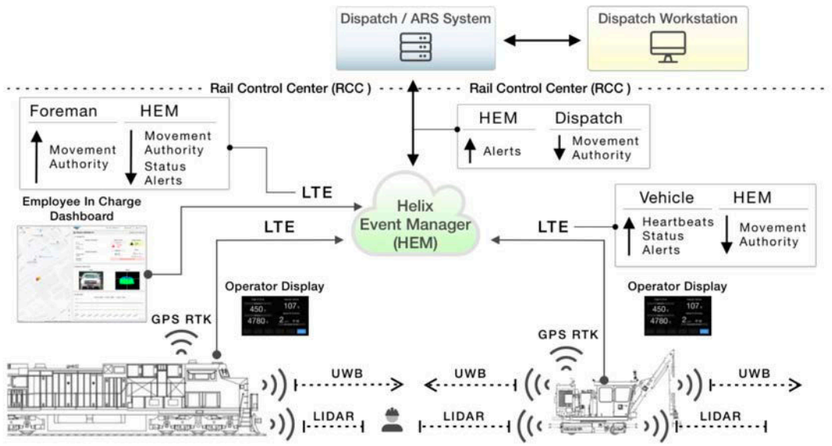
SYSTEM DESIGN

The SecureTrack System comprises three main segments: local, communications, and back office. The local segment includes sensors that continuously provide positioning data for nearby on-track equipment and personnel. It can be further broken down into the subsystems of an Employee-in-Charge (EIC) Application, Vehicle Operator Display (VOD), Roadway Worker Protection wearable, Master Control Unit (MCU), and Visual Processing Unit (VPU). For each vehicle installation, the MCU will sit on the vehicle's roof while the operator display and power supply box sit in the vehicle's cab. In most cases, each vehicle deployment will have a VPU in the front and rear of the car body. If the vehicle swivels, the amount of VPUs will be increased to four (4) to allow for a 360-degree field of view.

The local segment requires a communications segment to establish a data bridge between the local assets and the back office. This enables alerting and ensures compliance functionality. The communications segment comprises an onboard LTE modem that routes data to the Rail Control Center.

The back office segment comprises a redundant set of commercially available servers running custom-built software. The Piper Helix Event Manager (HEM) Server contains these servers and software and is the interface point.



1: WORK ZONE MANAGEMENT

A comprehensive work zone awareness system is crucial for railway track worker safety. With systems like SecureTrack, railway operators and track workers are equipped with tools to ensure safety in work zones and adequately manage potential hazards. The system's ability to define work zones remotely, alert approaching train operators through in-cab displays, and accurately monitor the presence of workers in the path of a train all contribute to maintaining a safe work zone environment.

Piper's cloud-based software integrates directly into Rail Control Center systems to create work zones in real time and interfaces with Maintenance-of-Way (MoW) systems that control work gangs, track and time, and other Employee-in-Charge management tools. SecureTrack is a common platform that adapts to each operator's unique protection rules based on track geometry, timing, location, and process such as fixed or moving work zones. This fully customizable and dynamic solution helps operators assess flagging and personnel requirements during the planning stages while providing live alerts for operators throughout the territory.

How it Works

The process begins with the Rail Control Center (RCC) selecting two defined points of interest locations on the wayside, marking the work zone's beginning and end. The Helix Event Manager (HEM) server then converts the generated PDF to a text format, extracts the limited information, and distributes it to the Employee-in-Charge (EIC) and MoW vehicles. Each LCCAS field asset periodically checks its dataset against the HEM server to ensure synchronization.

As an approaching train operator enters the work zone, they receive an audio notification, and the in-cab Vehicle Operator Display (VOD) changes from green to yellow, signaling the approach to a work zone area. The display turns red once in the work zone, and the operator is notified to stop the train.

EICs are equipped with ruggedized handheld devices or the Piper iOS application, enabling them to communicate directly with the train operator and providing clearance for the train to resume movement after a multifactor verification of safe clearance by workers.

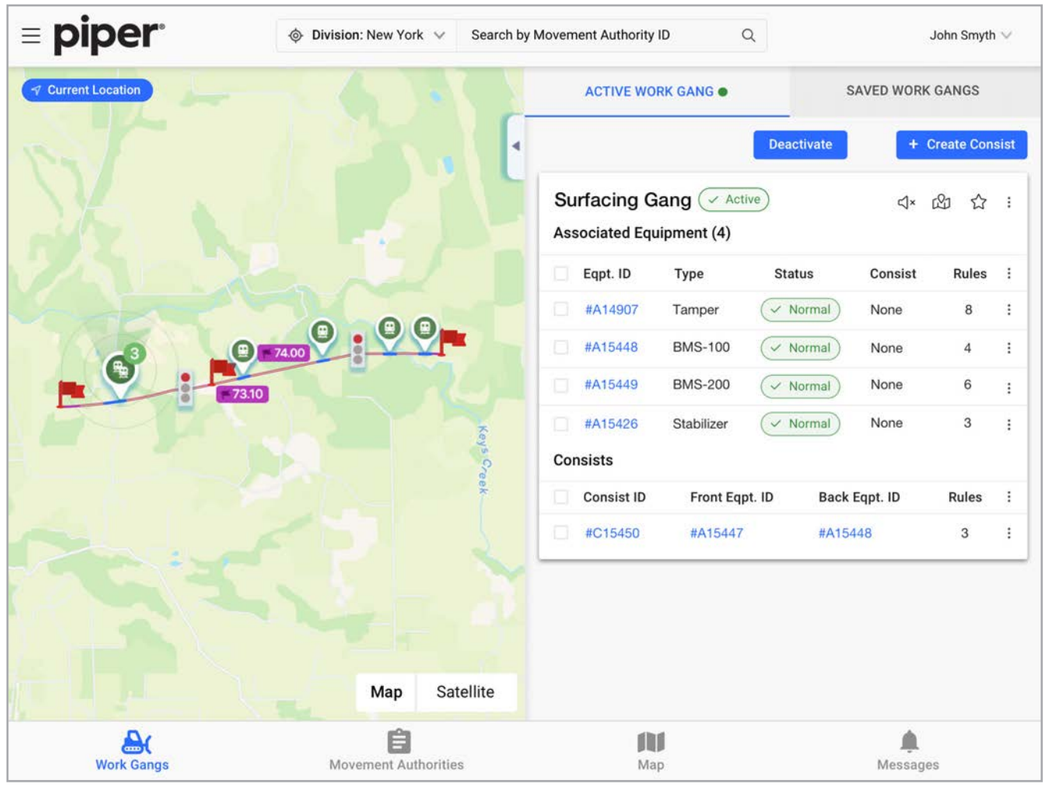
Once authorized, the display turns yellow again, and the train moves through the area at the required speed. When the rear of the train has cleared the safe zone, the display turns green, prompting the operator to resume full movement authority. The operator will receive warnings if the train is overspeeding or not maintaining a safe distance.

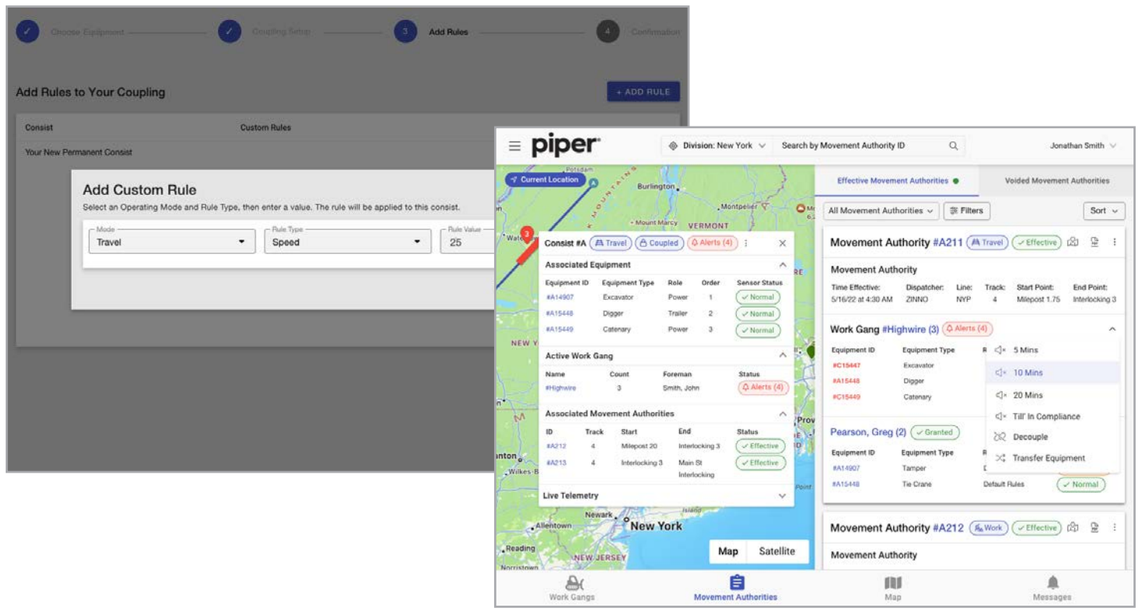
The local segment of the LCCAS system primarily relies on GPS RTK sensors to monitor compliance with limits locally. The system's local onboard database includes a baselined track centerline spline containing milepost data and the location of all signal masts for synchronization with the dispatch system. The GPS RTK provides centimeter-level positioning to determine precisely which track the vehicle operates without human intervention.

Employee-in-Charge (EIC) App

The EIC management display interfaces with our system using the Piper Fleet Manager App (FMA) that runs on an iOS-based iPad and provides the following management functions:

- Create and manage work gangs based on available MoW equipment, including the ability to merge work groups that originated from different locations.
- Display the geographical work area, the associated MoW equipment, and the display of work zone boundaries for limits compliance.
- Automated access, display, and execution of electronic Movement Authority / Track Out of Service or equivalent work order PDFs.
- Selection of current crew operating mode, incl. parked, travel, or working modes.
- Modification of alerting rules, which can be different based on each mode. For example, travel mode may have a different speed, safe distance to other vehicles, and obstruction distance.
- The EIC can associate with any Helix-equipped vehicle to receive notifications related to that vehicle ID or with a specific work group to receive notifications related to that work group.

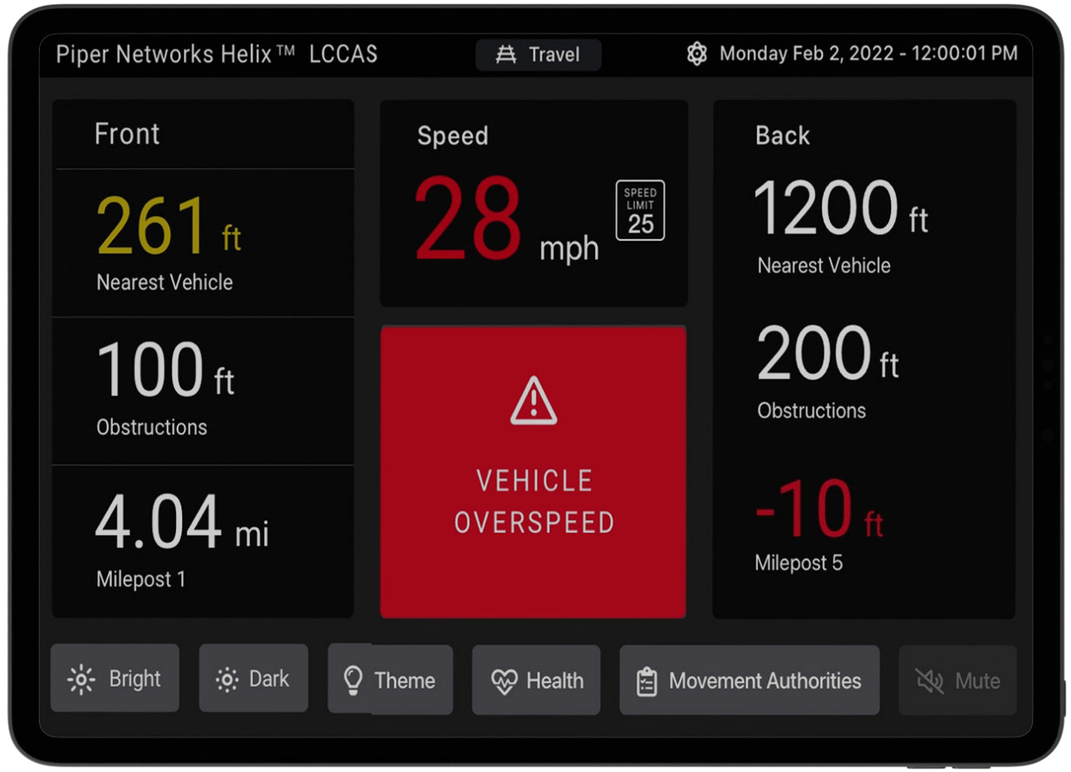




Vehicle Operator Display (VOD)

Piper’s Vehicle Operator Display (VOD) comes in various dimensions to fit seamlessly into any cab configuration, including ruggedized IP67 8-inch (20-cm) and 10-inch (25-cm) displays. This display provides real-time information to the vehicle operator, including relevant operational information and any mandatory directives issued to the vehicle. In the event of a safety condition, the VOD provides visual and progressive audible warnings to the operator before the optional brake application is applied. Operators can also temporarily mute alerts to prevent alert fatigue.

The VOD receives local sensor feedback to generate operator alerts. Feedback includes current speed/location, distance to the end of the movement authority, and distance to the nearest vehicles. The VOD allows the operator to cycle between day and night modes to use the appropriate color scheme for the visual data. Additionally, the VOD provides real-time information regarding the system's health, which the service / mechanical department uses to diagnose any issues and properly troubleshoot the system. The LTE modem sends this sensor data to the event manager in the cloud, which determines if a dispatcher or EIC alert is needed and relays the information to the EIC’s Fleet Manager App (FMA) and the dispatch system.



Examples of events leading to Warnings/Alerts:

- One or more MOW vehicles have left their assigned work areas.
- The assigned work area is canceled.
- LCCAS detects MOW vehicle(s) are still in the area.
- A MOW vehicle equipped with a crane or boom fouls a track.
- Transition between park, travel, and work mode.
- A vehicle’s accelerometer detects a collision.
- The on-track equipment violates the safe distance.
- A MOW vehicle infringes on the safe distance threshold of another MOW vehicle or obstruction.
- A vehicle is overspeeding.
- The on-track equipment approaches grade crossing or other TPOI.
- Sensor errors, heartbeats, or communication status.

2: ROADWAY WORKER PROTECTION (RWP)

Piper's Roadway Worker Protection (RWP) is an advanced wearable solution that detects workers fouling tracks in real-time. The multi-sensor solution is superior to existing safety systems because it provides centimeter-level accuracy even in congested RF environments, elevated tracks, and tunnels. The system's primary functions are locating the track worker within the work zone, communicating their position to approaching trains from all directions, and alerting the worker to those approaching trains.

The system alerts train operators visually and audibly when a worker is detected within 500 yards of the train's forward movement. However, given its high accuracy, Piper's proprietary algorithms, and Virtual Tunnels, it does not respond to the presence of workers outside the designated work zone, allowing trains to proceed unencumbered when no workers are detected.

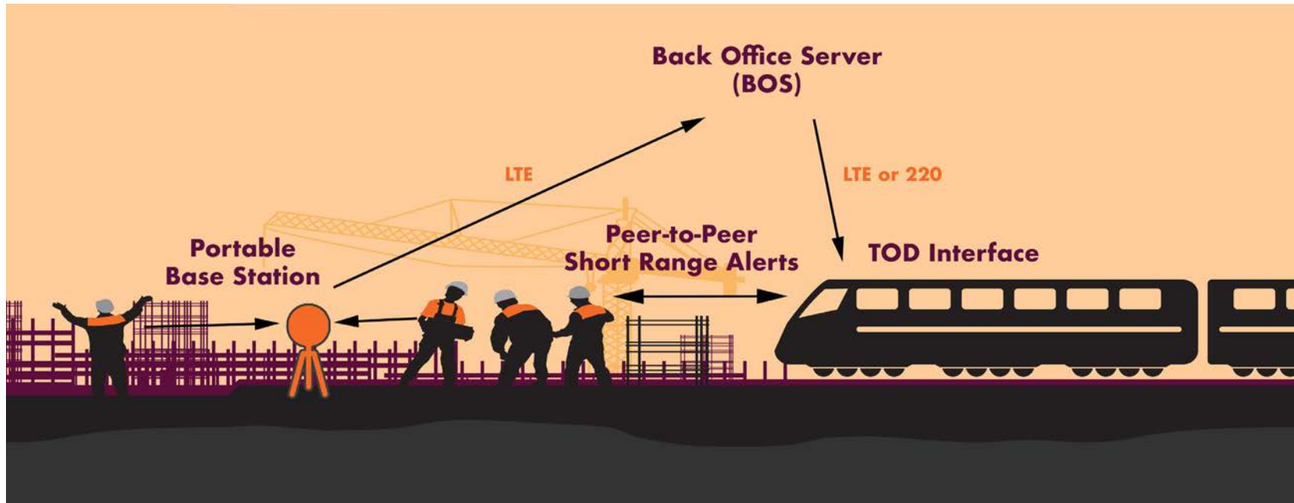
Piper's RWP wearable device, attached to an arm band, enables efficient radio communication and detection in all work modes. It features a long-life, rechargeable battery with a USB-C charging port or docking station that can operate for several shifts before requiring a charge. The device is IP-65 protected from water and dust, and encoded with unique IDs. It can securely store telematic data for offline analysis.

The wearable innovatively utilizes three radios to deliver a solution that can protect workers in all areas and conditions:

- **GPS** for localizing in elevated and ground-level areas based on the embedded GPS receiver in the wearable.
- **Ultra Wideband (UWB)** radio is used to localize the worker based on proximity to the wayside network of UWB fixed installation radios.
- **915MHz** radio for long-distance communication with approaching trains.

These wearables communicate passively with a portable base station and lineside communications network that combines LTE and GPS RTK. The base station transmits their position in an Earth-Centered Earth-Fixed NMEA format to the Back Office Server (BOS), which alerts train operators in the area of the worker's presence. Workers also receive audible alerts to warn of approaching trains. In the Short Range solution, the Piper RWP devices are capable of independent two-way communication with approaching trains and delivering audible alerts to the workers and audible and visual alerts to the locomotive operators - with no wide area network requirement.

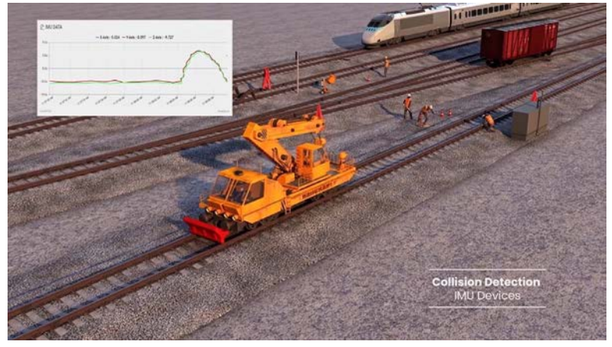
Piper Smart Flags are optional physical blue flags (lights) that can be installed on the tracks and include the same GPS-RTK/UWB functionality as the wearables and serve as an additional protection layer.

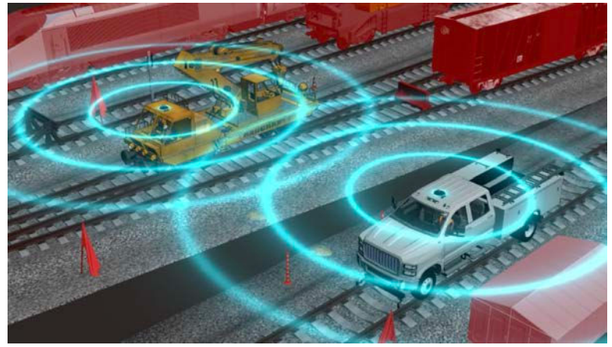


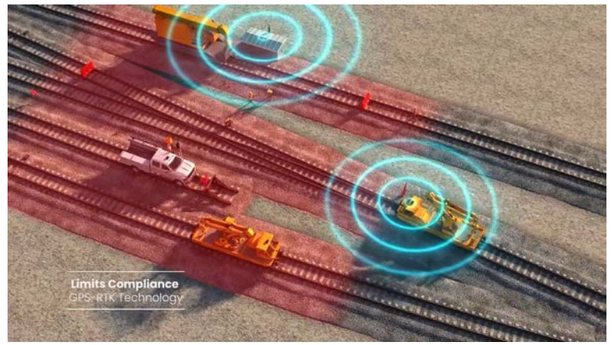
2: MAINTENANCE OF WAY (MOW)PROTECTION

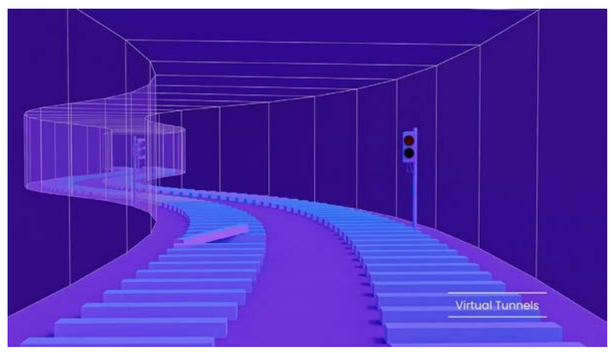
SecureTrack utilizes Piper's advanced Limits Compliance and Collision Avoidance System (LCCAS), which incorporates multiple sensors to provide railroads with a modular vehicle-centric safety system. Helix allows fleets of rail-bound and high rail equipment to be detected and tracked on the railroad. It is a safety overlay system that reduces the potential for employee and customer injury, equipment damage, and operational disruptions due to accidents or major rule violations. Helix incorporates multiple sensors to address several challenges that transit agencies and freight railroads face today, including:

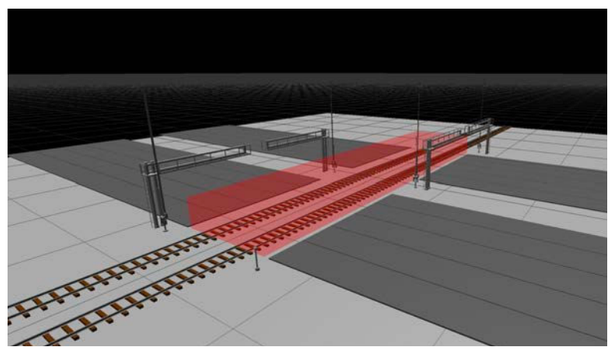
- **Collision Avoidance** - Ultra Wideband (UWB) radios provide collision avoidance between equipped vehicles and vehicle localization in complex junctions, yards, and areas where GPS is unavailable, like tunnels.
- **Obstacle Detection** - Piper's patented TrackSight™ LiDAR alerts operators to the presence of workers who inadvertently cross the track fouling area and objects that may be left in the vehicles' path.
- **Limits Compliance** - GPS-RTK provides a high precision position & speed calculation for limits compliance and time synchronization.
- **Collision Detection** - Onboard Inertial Measurement Unit (IMU) uses gyroscopes and accelerometers to detect collisions and alerts the EICs immediately.
- **Event Recorder** - HD Cameras capture outward-facing and in-cab video for forensic purposes in the event of an incident.
- **Virtual Tunnels** -Reduce false positives by distinguishing between objects breaching the fouling area or creating a hazard from necessary and existing wayside infrastructure such as signal heads or gantries.











Ultra Wideband (UWB)

UWB systems can provide precise positioning and tracking capabilities, making them well-suited for safety-critical applications in the railway industry. The mobile UWB radio units work with three or more fixed line-side wide frequency band radio beacons to determine a train's position. UWB uses short-duration radio pulses to penetrate obstacles and provide accurate range and positioning, even in challenging and dynamic environments. It also relies on a time-of-flight (TOF) method to calculate the distance from a nearby UWB radio.

Piper's carborne UWB radio can provide two levels of protection for rolling stock and roadway workers. The first is absolute positioning, which calculates the distance from the onboard UWB radio to the surveyed fixed-position UWB radios installed on the wayside. The wayside radios require only power and intentionally do not require a WAN for operation or monitoring. The onboard UWB radios connect to the MCU. The MCU then calculates the absolute position based on a surveyed reference database comprising a track spline and Points of Interest markers. These markers initiate advisories to the operator and enforce temporary speed restrictions or braking actions based on hazardous operations.

The second level of protection is derived from using the onboard UWB radios to provide peer-to-peer measurement of vehicle separation. Separation is beneficial for MoW vehicles that often operate nearby and requires an additional layer of safe separation assurance to reduce the potential for MoW-to-MoW or train-to-MoW collision.

SIL4 Safety Certification

Piper Networks has received a CENELEC Safety Integrity Level 4 (SIL-4) Certification for its Ultra Wideband (UWB) train control system from independent safety assessor TÜV SÜD. The certification is a milestone achievement for Piper and the transportation industry as it becomes the first-ever UWB-based position and speed technology to achieve vitality. The system is now ready for integration with transportation agencies and their engineering contractors, who implement signaling and train control programs in the US and worldwide.

Applicable Standards

Piper's RPS has achieved functional safety certification to a SIL-4 level for the following standards:

- EN 50126 Railway Applications: The Specification and Demonstration of Reliability, Availability, Maintainability & Safety (RAMS) v.2017
- EN 50128 Railway applications - Communications, Signaling and Processing Systems – Software for railway control and protection systems v.2011
- EN 50129 Railway applications - Communications, Signaling and Processing Systems – Hardware for railway control and protection systems v.2018
- EN 50159 Railway Applications - Communications, Signaling and Processing Systems – Safety Related Electronic System for Signaling, February 2003, 2010
- EN 50155 Railway applications - Electronic Equipment Used on Rolling Stock v.2017

Piper also meets the following standards for EMI/EMC/Environmental compatibility:

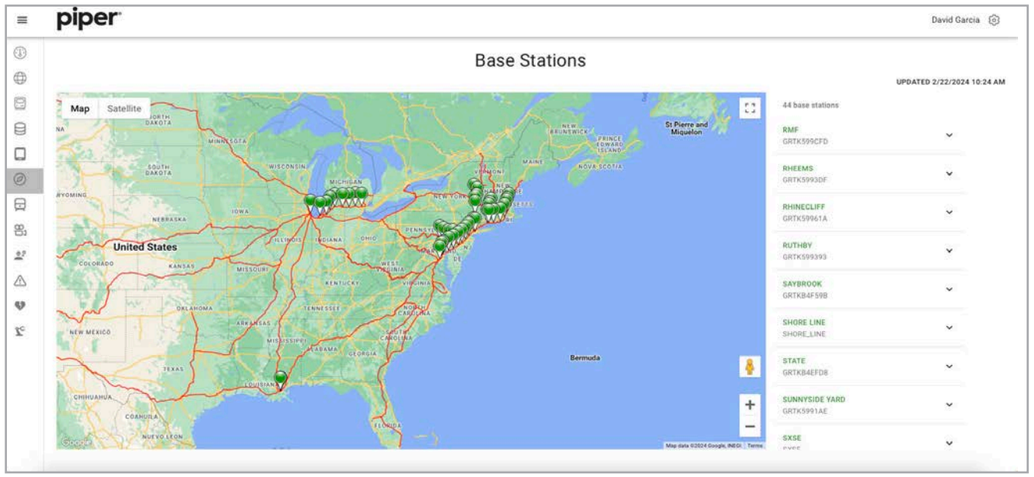
- EN 50121-1 - Electromagnetic compatibility
- EN 50121-3 - Rolling Stock - Train And Complete Vehicle
- EN 50121-4 - Emission And Immunity Of The Signaling And Telecommunications Apparatus
- EN 50155 - Electronic Equipment Used on Rolling Stock
- IEC 60068-2 - Environmental Testing of Electronic Equipment
- AREMA C&S 11.5.1 (Class B)

GPS Real Time Kinematic (RTK)

GPS plays a significant role in monitoring vehicle locations by providing real-time data for dispatchers and operators. GPS-RTK (Global Positioning System Real Time Kinematic) takes things a step further and offers several key benefits over standard GPS, which provides only meter-level accuracy and is susceptible to factors like atmospheric interference, satellite clock errors, and multipath reflections that can further degrade accuracy. Conversely, RTK delivers centimeter-level accuracy that opens up unique benefits.

Piper's GPS-RTK utilizes a network of fixed base stations with known, precise locations along the railway lines. Piper's convenient 1U rack-mounted base stations can easily be installed and protected in the wayside PTC huts. These stations continuously transmit correction data to mobile receivers on trains using NTRIP (Network Transport of RTCM via Internet Protocol) as a protocol. The receivers combine data from GPS satellites and base stations, achieving centimeter-level accuracy (even sub-centimeter in some cases). This real-time correction eliminates errors, making train positioning highly reliable.

GPS relies on signal availability, so obstacles like tunnels or buildings can disrupt satellite signals. Piper considers this by offering redundant positioning systems using Piper's wayside Ultra Wideband radios and Piper's patented train-centric LiDAR called TrackSight™. In the case of Piper's Limits Compliance and Collision Avoidance System (LCCAS), when the view of the sky is obstructed, the system may rely on the live LiDAR data relative to the survey map to assist with navigation until the GPS-RTK is restored. In cases where the GPS-RTK and TrackSight™ are unable to compute position, the Piper LCCAS system will rely on the IMU for dead reckoning until the GPS-RTK or TrackSight™ can compute its following position report.



Piper knows that implementing and maintaining GPS-RTK infrastructure can be expensive, so we optimize the system for increased coverage and reduce the number of base stations needed. For example, Piper only required 35 base stations to cover the entire Northeast Corridor (NEC).

Visual Processing Unit (VPU)

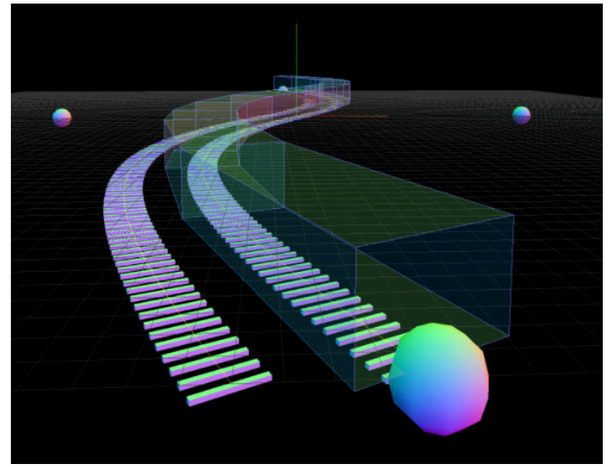
The following sensors make up the VPU.

TrackSight LiDAR

Light Detection and Ranging (LiDAR) technology is used in railways and trains for various purposes, including obstacle detection, distance measurement, and mapping of the surrounding terrain. It helps ensure safety by detecting any obstructions on the tracks and providing accurate data for control systems. Furthermore, lidar aids in monitoring the surroundings for maintenance purposes and creates detailed maps for infrastructure planning.

Piper developed TrackSight™ as a patented means for processing LiDAR data with a low-power onboard computer. TrackSight™ leverages the power of a 64-bit, 125-scan line resolution Solid State LiDAR sensor. It can deterministically localize a rail vehicle and monitor its field of view for objects that do not match its known database. Solid-state LiDAR is a form of LiDAR that does not require moving parts, is smaller and more resilient to vibrations, and is often less expensive than an electromechanically-intensive traditional LiDAR system, thanks to being built entirely on a silicon chip and reflective mirrors. Where a typical automotive LiDAR system is mounted to a vehicle and physically moved to change its direction, solid-state LiDAR can adjust its directional focus by changing the patterns of its optical emissions. Adaptability is attractive to rail operators as it eliminates the need for a swiveling LiDAR sensor mounted to a vehicle (or many LiDAR sensors locked in place to cover blind spots).

To detect obstacles that could result in a collision with the operating vehicle, the TrackSight™ system will be calibrated to focus its field of view toward the direction of the track. The TrackSight™ LiDAR sensor can be configured to ignore any observed objects that don't meet the minimum size threshold to avoid false positives caused by common debris.



The TrackSight™ sensor considers the database on the local CPU to dynamically focus its field of view when the vehicle approaches a curve or the track changes elevations. The following image is a screenshot of our database building tool illustrating a multi-track configuration with the TrackSight™ LiDAR focusing its field of view to monitor obstructions through the curve.

Additionally, TrackSight™ can determine its distance from observed objects and notify the equipment operator of when they should prepare to stop based on its current speed.

High Definition (HD) Video Camera

Exterior and in-cab HD video cameras are installed to record footage, enabling the capture of detailed visual evidence that can be utilized for forensic analysis in the unfortunate event of an incident. These cameras offer a clear visual representation of the operating environment, providing valuable insight into the conditions the operator faces.

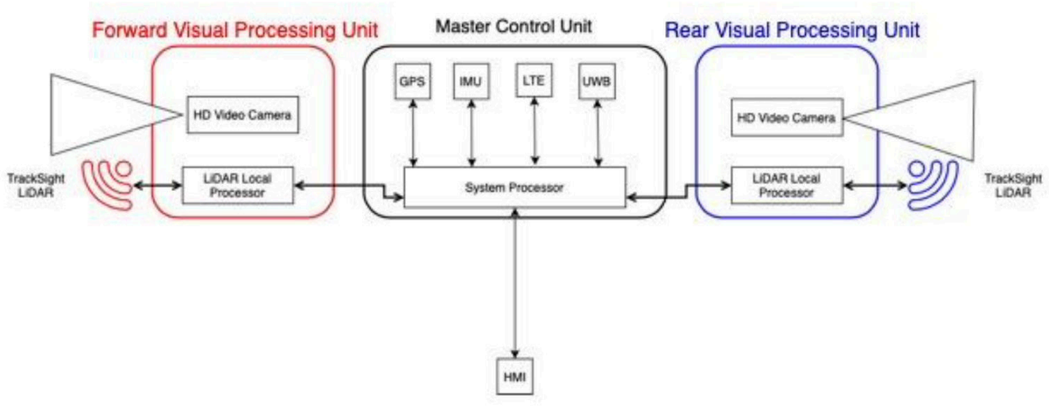
Master Control Unit (MCU)

The MCU is located on top of the vehicle, between the two VPUs or outward-facing sensors. It comprises the Computer Processing Unit (CPU), Inertial Measurement Unit (IMU), and LTE antennae for communication.

Helix Computer Processing Unit (CPU)

A CPU (central processing unit) is essentially a computer's brain. It carries out a computer program's instructions by performing basic arithmetic, logic, control, and input/output (I/O) operations specified by the instructions.

The GPS-RTK, LiDAR, and Ultra Wideband sensors are integrated into the vehicle's system. These sensors feed data into the Helix CPU, which is responsible for processing the various inputs and providing critical feedback to the vehicle operator,



Inertial Measurement Unit (IMU)

The Helix IMU includes a digital signal processor called Motion Processor, which fuses acceleration and gyroscope data. The Accelerometer measures physical acceleration, while the gyroscope measures angular/rotational velocity. Piper's IMU accelerometer measures acceleration in meters per second squared. Piper then converts each acceleration into a g-force measurement to give the LCCAS system an understanding of any collisions on the local asset. While the TrackSight™ and UWB sensors will enable the Helix system to alert the vehicle operator, EIC, and Dispatcher when a collision is imminent, the IMU will allow Helix to alert the EIC and dispatcher when a collision occurs immediately. Additionally, the IMU gives the Piper LCCAS system the added function of dead reckoning for enhanced availability.

Communications

The communications segment will consist of an onboard LTE modem routing data to the Rail Control Center. Piper would propose utilizing the LTE providers of the agency's PTC system or the PTC 220-MHz data network in addition to LTE if there is reliable coverage throughout the network.

The LCCAS EIC Terminal will leverage the local systems data network to synchronize with the Piper Helix Event Manager (HEM) server. If Piper delivers a mobile application, the EIC application will use the data network on the installed device. If Piper delivers the physical tablets, we will provide tablets with LTE connectivity.

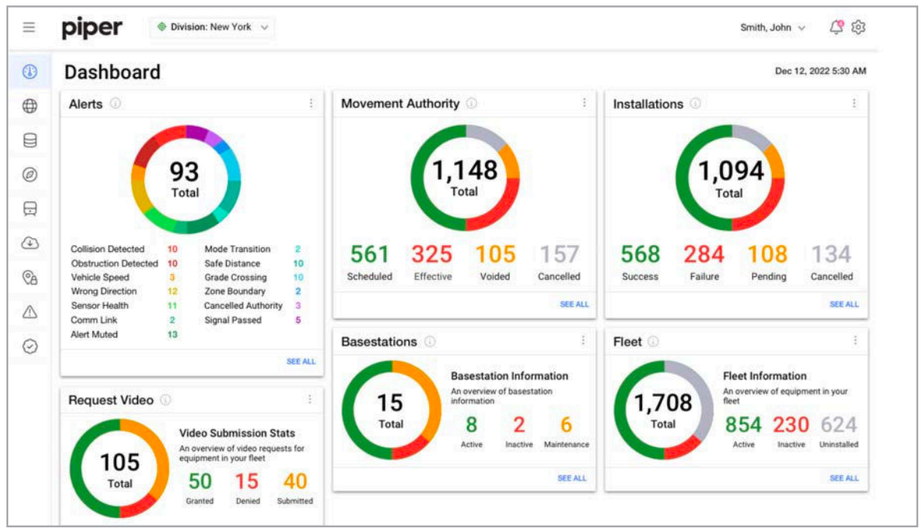
Maintenance of Way Protection

Helix Event Manager (HEM)

Monitoring and managing remote assets is crucial for the safe, effective, and regulatory-compliant operation of Rail Systems. If applicable, the Rail Control Center (RCC) can integrate the Piper HEM system as a standalone application or as an input to an existing Asset Management system. The Piper HEM implementation provides the necessary functionality for remotely monitoring Helix-equipped vehicles. Additionally, HEM deploys and configures Helix software remotely and can take corrective actions to resolve onboard problems.

The software and integration effort's primary focus is the automated delivery of movement authority and system advisories from the Rail Control and Dispatch Center to locomotive operators and EICs managing roadway workers. This integration will include a robust list of rail control functionalities and corresponding system monitoring dashboards and HMI displays for the locomotives and EIC-issued tablets.

All assets report a configurable amount of health statuses, enabling the operations team to conduct trend analysis, react quickly to malfunctioning devices, and determine a preventive maintenance schedule.



The Piper HEM system provides three (3) feature sets, described below:

Remote Monitoring

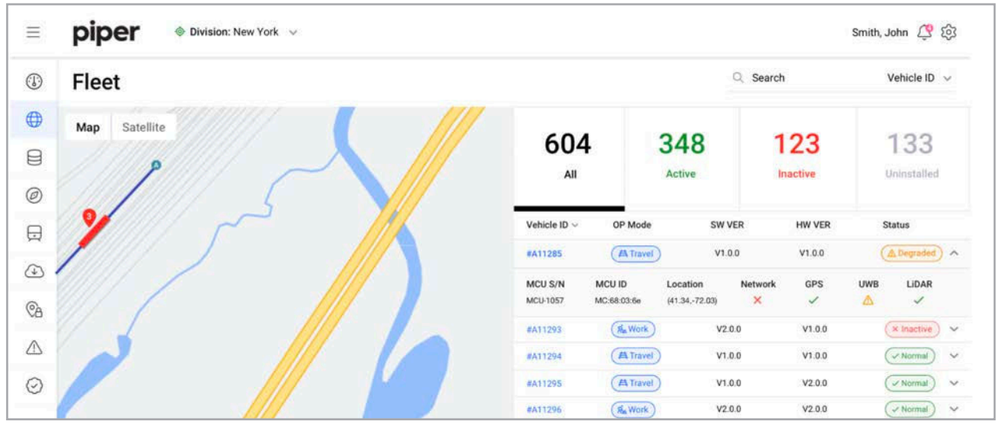
- Periodic Monitoring - Periodically sends asset messages and trending data.
- Detected Conditions - Alert on specified asset changes or out-of-normal conditions, e.g., high radio temperature, firmware version change, etc.
- On-Demand Monitoring - Perform specific monitoring actions on demand, e.g., query current configuration parameters.
- Monitoring management - Provide remote management functions, e.g., modifying configuration parameters or performing corrective action.

Remote Software Deployment

- Remote deployment allows users to stage, verify, install, modify, roll back, and uninstall packages remotely with complex rules and condition checks.

Remote Readiness Checks

- The system can check and return asset information and status for onboard subsystems. A scoring system (for example, Pass/Fail or rate a unit from 1 to 10) can assess the onboard system's current state and compare the units' relative readiness.



Piper believes that the approach we have defined in this document will help agencies reduce costs in the short term while reducing obsolescence risks for years to come. Our team is highly competent in implementing advanced railway safety systems, with a proven track record and a deep understanding of regulatory requirements. We are committed to excellence and staying at the forefront of technological advancements, making us the ideal partner for ensuring railway safety and operational effectiveness. We welcome the opportunity to schedule a follow-up meeting to discuss the details and answer questions from the agency and their GEC.

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