M E M O R A N D U M

SUBJECT: Wayside Detection Maintenance History

DATE: April 25, 2022

FROM: Diane Holland
Assistant Manager (CENV)

[redacted]

THRU: Shushil Ramnaress
Vice President & Chief Mechanical Officer (CMOR), Acting

TO: Joey Rhine (NTSB)

This is in response to the NTSB request, dated 03/31/2022 for a description and comprehensive maintenance history for each of the wayside detector installations on WMATA system.

1. TRUCK PERFORMANCE DETECTOR (TPD)

a. TPD Background

MxV Rail, formerly Transportation Technology Center, Inc. (TTCI), Pueblo, Colorado, developed the original TPD under the AAR's research program in mid-1990. The TPDs measure wheel/rail forces via strain gauge sensors on the rails in selected curves.

TPD systems identify railcar truck suspension systems that do not perform optimally in curves or following negotiation of a curve. Poor performance may result in derailments due to wheel climb, gauge spreading, rail rollover, and track panel shift. In addition, it contributes to wear on special track work, wheel profile, flanges, and rails. Through performance-based preventive action, the safety of rail operation can be improved. This improvement comes from identifying poor vehicle performance so that preventive maintenance can be performed before a derailment risk exists. A TPD can indicate poor truck performance via measured forces such as the L/V ratio.

Vehicle dynamic monitoring and data analysis identify certain number of vehicles exceeding the established alert criteria. To date, WMATA has two (2) TPD installed sites, at Greenbelt and New Carrollton railyards. Each site has two (2) alert levels, medium and high severity level. New

Washington
Metropolitan Area
Transit Authority

Carrollton yard alert levels are higher than Greenbelt, due to tighter curvature. Severity levels are identified by single wheel L/V value.

Medium severity is intended to be a warning for vehicle not meeting expected performance, and high severity level is a warning for pending maintenance action. Depending upon the L/V value, the high severity level/alert could be a clear indication the vehicle may need to be removed from service for inspection and corrective action. The vehicles exceeding the high severity alert level exhibit poor curving performance and high lateral forces. Removing these vehicles from service and performing corrective action(s) reduce the component failures and minimize impact on overall infrastructure and mostly decrease the derailment risk.

Data collection begins as the detector determines a train is approaching. Each wheel produces a force signature that is captured and held until the train is completely past the site. These values represent the peak forces (lateral and vertical) induced on the rail by the wheel at the moment it crosses the strain gauge sensor. AEI tags on the vehicles are read simultaneously as the train passes and merged with force data to produce a consistent and complete train set.

b. TPD Specification

Table 1 below shows specific information about the manufacturer, model, capabilities, and specifications of the TPD system.

Table 1: TPD Specification	
Manufacturer	Instrumentation Services, Inc (ISI) Note: Originally TTCI + InteRRIS, ISI was the OEM equipment provider and installer from 2005-2020
Model	Truck Performance Detector
Capabilities	Wheel / Rail L/V forces plus AEI tag Alerts sent for cars with high L/V
Specifications	See Attachment “A”
Plan for new installation and their capabilities	No plan for new TPD installation

Table 2 below shows the location, installation date, and latest disrepair with repairs that were completed on April 23 and 24, 2022.

Table 2: TPD System Overview at Greenbelt and New Carrolton Yards		
Location	Greenbelt Yard Lead Chain Marker: (YL1) 11+00	New Carrolton Chain marker: (Lead Track 1) 16+60
Date Installed	January 2005	October 2007
Date in service	January 2005	October 2007
Date defective (Out of service)	July 2020	Detector in service
Reason for disrepair	Strain gage failure 1 of 12, failed computer, outdated 3G wireless data modem	Strain gage failure 1 of 12, outdated 3G wireless data modem
Latest repairs	Replace computer and power supply, upgrade 3G data modem to 4G, calibrate L/V gages, verify reading of 7K AEI tag, resume data service	Replace failed strain gage, upgrade 3G data modem to 4G, calibrate L/V gages, resume data service.

c. Maintenance History

Refer to attachment "E" for the comprehensive maintenance history of both TPD systems.

2. AUTOMATIC WAYSIDE INSPECTION SYSTEM (AWIS)

a. AWIS Background

Washington Metropolitan Area Transit Authority (WMATA) has initiated a procurement of multiple Automatic Wayside Inspection Systems (AWIS or System), including delivery, installation, commissioning, validation (Contractor certification of system safety, accuracy, and precision), and a four-year support program.

There is currently one (1) installed AWIS at Greenbelt yard that was installed in February 2020 by Track IQ, a WABTEC Company. However, installation was incomplete as the lasers were not ready at the time of the initial installation. The system was running / functioning at reduced capability. On November 2021, the exterior lasers were installed and configured, pending interior laser / camera and final calibration.

Since the October 2021 derailment of rail vehicle 7200, WMATA's need to enhance the collection and analysis of certain measurements of the wheel sets on revenue vehicles has become critical. Therefore, WMATA is pursuing the procurement and installation of six (6) AWIS for mainline installations to improve current manual measurements process. The additional AWIS are contracted by KLD, a different manufacturer.

b. AWIS Specification

Table 3 below shows specific information about the manufacturer, model, capabilities, and specifications of the current installed AWIS system.

Table 3: Track IQ AWIS Specification	
Manufacturer	Track IQ, a WABTEC Company
Model	See Attachment "B"
Capabilities	See Attachment "B"
Specifications	See Attachment "B"
Plan for new installation and their capabilities	See Attachment "C" for KLD AWIS Technical Information of the additional system. See Attachment "D" for the six (6) planned KLD AWIS mainline locations and tentative schedule.

	Wheel Detection Monitor: • Wheel Set Back-To-Back / Inner Gauge Measurement • Wheel Profile • Flange Height • Flange Width • Hollow Tread • Rim Thickness/Diameter • Flange Angle/Flange Slope • Flange Back-Wear • Wheel Width • False Flange • Outer Metal Flow • Tread Build-Up • Vehicle / Truck / Axle / Wheel (side) ID Truck Condition Monitor: • Angle of Attack • Tracking Position • Interaxle Misalignment • Tracking Errors • Rotation and Lateral Shifts

Table 4 shows the location, installation date and latest disrepair with planned repairs of the one (1) installed AWIS system.

Table 4: TRACK IQ AWIS Overview at Greenbelt Yard	
Location	Greenbelt Yard Lead YL1 between signals 62 and 42 AWIS pilot installation
Date Installed	February 2020 - System installed without the lasers November 2021 - Exterior lasers installed and configured, with interior laser/camera remaining to be installed (bracket / fixation issue).
Date in service	March 2020 – Reduced capability
Date defective (Out of	AWIS was installed in February 2020, but installation

service)	was incomplete, as the lasers were not ready from contractor at the time of initial installation
Reason for disrepair	AWIS was installed in February 2020, but installation was incomplete, as the lasers were not ready from contractor at the time of initial installation
Ongoing / Upcoming work	Installation of two interior lasers (enhance brake disc imaging/measurements), and completion of calibration of the pilot system over the upcoming 90 days.

c. AWIS Maintenance History

Refer to attachment "E" for the comprehensive maintenance history of AWIS system.

Thank You.

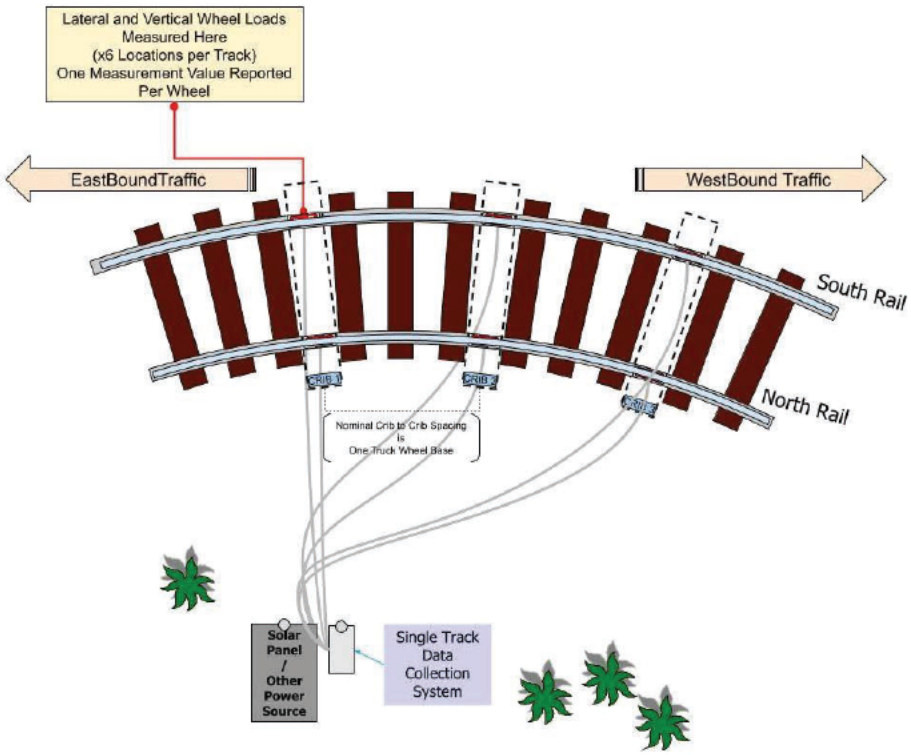
Attachment A: TPDLV Datasheet v01
Attachment B: AWIS Pilot (Track IQ – a WABTEC Company)
Attachment C: KLD Labs WheelScan Tech Info
Attachment D: AWIS Locations Schedule (KLD)
Attachment E: TPD & AWIS Maintenance History

Instrumentation Services, Inc.
6547 N Academy Blvd #558
Colorado Springs, CO 80918 USA
Phone: 719 [redacted]
Fax: 719 [redacted]
e-mail: [redacted]

L/V Wheel Rail Force Measurement System for Truck Performance Detector – Transit Application

Truck Performance Detector Overview

ISI's TPDs acquire data from vertical and lateral load strain gage circuits installed on the rails in 3 cribs at a typical single-curve location. L/V wheel loads are matched with AEI tag reader data to identify passing rail vehicles. Collected data is checked against performance criteria, to pick out rail vehicles with poor vehicle-track interaction performance. Key Truck Performance Parameters include Lead-Wheel L/V Ratio, Truck-Side L/V Ratio, Gage Spread Factor, and Truck Warp Index.



Typical TPD L/V Site - Single Track Curved Location
ISI LV Site for Transit Railcar Truck Performance Detector 2018

South Rail = High Rail
North Rail = Low Rail

Instrumentation Services, Inc. • 6547 N Academy Blvd #558 • Colorado Springs, CO 80918 USA
719 [redacted] (office) • 719 [redacted] (fax) • [redacted] (email)

Instrumentation Services, Inc.
6547 N Academy Blvd #558
Colorado Springs, CO 80918 USA
Phone: 719 [redacted]
Fax: 719 [redacted]
e-mail: [redacted]

ISI L/V Remote Data System Specifications and Features

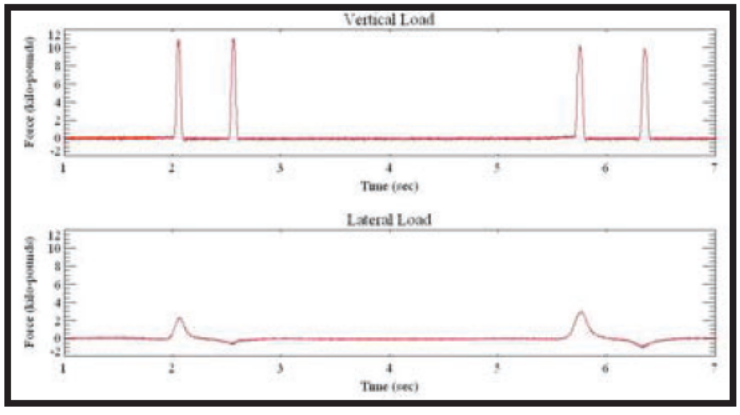
Instrumentation Services' TPD systems utilize ISI's proven Remote Data System technology. ISI's Remote Data System (RDS) is optimized to reliably collect data from strain-gaged rails, measuring the Lateral and Vertical Wheel/Rail forces of passing trains. L/V sites are installed at numerous test locations, providing reliable, cost-effective data for: Vehicle/Truck Curving Performance, Wayside Lubrication Trials, Track Geometry Effects, and on-board dynamic testing and rail-vehicle modeling validation.

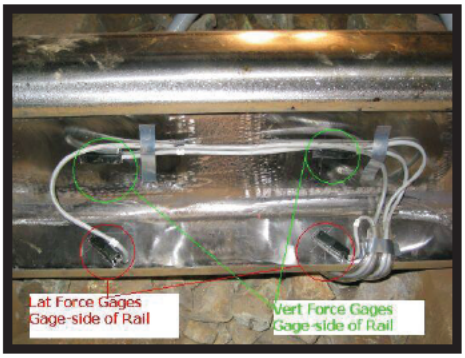
Truck Performance Detector Notification and Reporting Capabilities

The Truck Performance Detector provides capability for several levels of notification and reporting. Notifications are sent to maintenance personnel, alerting to the need for corrective action. Detailed L/V information is sent to a centralized database(s) for archive and additional reporting.

Data Reporting

- Important Truck Performance Detector Data for every car transmitted to centralized database(s)
  - Single point-of-interface to access data from all ISI TPD sites
  - Site ID, Car Reporting Marks (AEI), Date and Time of Measurement
  - Individual L/V Wheel Loads
  - Detailed data forwarding to 3rd party databases (TTCI/InteRRIS, etc.)
- Train Summary (date, time, speed and direction of train, average lateral loads by lead/trail axle)
- Detail Data (Speed, Lateral and Vertical force for each wheel in the train at each crib/rail)
- Automated, Remote data and notification delivery via Web, FTP or e-mail





Instrumentation Services, Inc. • 6547 N Academy Blvd #558 • Colorado Springs, CO 80918 USA
719 [redacted] (office) • 719 [redacted] (fax) • [redacted] (email)

Instrumentation Services, Inc.
6547 N Academy Blvd #558
Colorado Springs, CO 80918 USA
Phone: 719 [redacted]
Fax: 719 [redacted]
e-mail: [redacted]

ISI Truck Performance Detector System Components

Strain Gage Circuits for Lateral and Vertical Load Measurements ..... 3 cribs

- ISI standard L/V strain-gage circuits installed and calibrated
- three (3) cribs of lateral and vertical load circuits installed on both high and low rails in a curve

Data Collection System ..... 16-channel / 3-crib system

- ISI Remote Data System (data collection and processing computer)
- Includes software for TPD L/V threshold checking and reporting
- 14 channels strain gage signal conditioning (3 cribs)
- on-site communications network connection for system configuration, peer-system interface and data download
- standard-size pole-mount enclosure to contain computer, signal conditioners & backup power system (for AC power applications; solar applications require larger enclosure)

AEI Reader SmartPass

- One SmartPass AEI Reader for track-side mounting and interface to Remote Data System
- Records AEI tags from passing trains

L/V Calibration

- After the TPD is installed and operational a system calibration is performed by applying known loads to the circuits and recording this against the measured value
- ISI's L/V calibration fixture consists of a pair of twin A-frames to apply rail vertical loads and a lateral loading arrangement to apply a gauge spreading force
- Full-System / In-Situ Calibration at each of 6 L/V measurement locations (cribs)
- Re-Calibration is recommended at 2-year intervals, or more frequently in heavy traffic locations

Cellular Data Modem

- Provides remote download collected data directly to ISI TPD database. Includes data-modem hardware and external, hi-gain antenna.

Ongoing Data Service

- Monthly fee for cellular data service, secure data archive website, and ISI tech support

System Integration and Local Customization

- ISI can provide technical support to configure local, customized data delivery, reporting and notification

Optional System Components

Solar Power System

- 200-W panel capacity, 5-day battery capacity, automatic solar charge controller, oversized weatherproof enclosure for all equipment (including batteries and data system), poles and mounting hardware

Instrumentation Services, Inc.
6547 N Academy Blvd #558
Colorado Springs, CO 80918 USA
Phone: 719 [redacted]
Fax: 719 [redacted]
e-mail: [redacted]

Equipment Warranty

- ISI standard warranty covers any defects in Remote Data System and Vertical strain gage workmanship and installation for a period of 1 year after system installation.
- Any failures of installed system components (sensors, cables, signal conditioners, computer software or hardware, solar power system) will be repaired or replaced by ISI for a period of 1 year after installation
- Damage to system components (sensors, cables, signal conditioners, computer software or hardware, solar power system) is not covered under ISI's warranty, but ISI will offer repair or replacement at customer's expense. ISI makes an effort to protect the on-track equipment and to install it as to avoid damage; however, damage caused by railroad track maintenance activity or equipment, or other railroad operations is not covered under warranty. Damage due to vandalism is not covered. Damage due to lightning or other "acts of God" is not covered.

Requirements of Local Track Owner

- provide on-track safety (lookout / track&time protection) during installation
- perform preliminary site work: installation of trackside enclosure, AC power (single-pole 15A circuit 110VAC/60Hz) and communications infrastructure at selected site(s), as required by site specific conditions

Functional Details and System Components

- Typical single-curve location for Truck Performance Detector – Transit Rail Vehicles
- ISI standard L/V gage circuits installed on both rails (high and low in curve)
- Environmentally sealed, weldable strain gages
- Cables routed through durable, weatherproof flexible conduit from rails to track-side system enclosure
- High-Isolation, industrial-class signal conditioning for strain gage signals
- AEI Tag reader to acquire carIDs of passing railcars, to aid in data analysis by car types
- Low-power data collection computer with 133MHz processor, 16-channel A/D, 2 months on-site, historical data storage
- 4G Cellular Data Modem for remote, automatic data download
- standard-size, weatherproof trackside enclosure to contain computer, signal conditioners & backup power system (for AC power applications; solar applications require larger enclosure)
- (Optional) Solar power system designed to provide continuous L/V measurement system operation: solar panels, charge controller and battery backup. Includes oversize, weatherproof system enclosure to house batteries and power-system components

Instrumentation Services, Inc. • 6547 N Academy Blvd #558 • Colorado Springs, CO 80918 USA
719 [redacted] (office) • 719 [redacted] (fax) • [redacted] (email)

Instrumentation Services, Inc.
6547 N Academy Blvd #558
Colorado Springs, CO 80918 USA
Phone: 719 [redacted]
Fax: 719 [redacted]
e-mail: [redacted]

TPD Equipment Specification - Site and Track Layout Requirements

1. Single Curve Track Location for Transit Rail Vehicle TPD
    a. Curve Length: minimum 200 ft full-body
    b. Grade / Slope: Ideal is level track, but practical is minimal slope, with normal operating / prevailing traffic direction up-grade preferred
2. Train Operating Speeds
    a. 5 to 200 mph, steady thru-train speed
    b. Ideal site will have most trains operating near balance speed, and minimal variation in typical train speed
    c. Preferred sites will have limited number of train-stoppage over the site
3. Rail L/V Measurement Locations
    a. 3 total L/V cribs, both rails, in one single curve track location
    b. spaced nominally 1 truck-wheel base between adjacent measurement cribs
    c. Good Track Condition, 20" – 24" tie spacing, good ties with fasteners and tie plates in good condition, ties square to rail (not skewed)
4. AEI Tag Reader Location
    a. 1 location (typically in Tangent) fitted with AEI Tag Reading equipment to allow automated rail-vehicle identification

Instrumentation Services, Inc.
6547 N Academy Blvd #558
Colorado Springs, CO 80918 USA
Phone: 719 [redacted]
Fax: 719 [redacted]
e-mail: [redacted]

TPD Equipment Specification - Measurement Requirements - L/V Strain Gages on Rails

1. Lateral Strain Gage Circuit
    a. Configured to allow direct measurement of Lateral wheel/rail force of individual passing wheels
    b. Installed on base / foot of rail, both high- and low-rails in curve, and both running rails in tangent
    c. Calibrated after install, using lateral spreader calibration fixture
    d. typical +/- 5% measurement accuracy
2. Vertical Strain Gage Circuit
    a. Configured to allow direct measurement of Vertical wheel/rail force of individual passing wheels
    b. Installed in web of rail, both high- and low-rails in curve, and both running rails in tangent
    c. Calibrated after install, A-Frame calibration fixture
    d. typical +/- 3% measurement accuracy
3. Strain Gage Installation and Cabling
    a. factory-sealed, weldable strain gages
    b. Use environmental conduit to protect cable runs
    c. Utilize shielded strain gage lead-wire
    d. Utilize shielded/twisted pair bridge extension (2-pair / 4-wire) cable
    e. Use simple 4-wire strain gage wiring (+/- Excitation and +/- Signal only) (no remote-sense, remote-cal)
    f. Tie cable shields to ground at only one end (DAS); leave other end "floating"
    g. maintain electrical isolation between sensors and rails (do not tie any shields at rails, etc.)
    h. Minimize cable lengths / avoid cables running along-side track

TPD Equipment Specification – Calibration

1. L/V Strain Gage Calibration
    1. After the TPD L/V System is installed and operational a system calibration is performed by applying known loads to the L/V strain gage circuits and simultaneously recording the strain gage response signals.
    2. Full-System / In-Situ Calibration at each of 3 L/V measurement locations (cribs)
    3. Vertical and Lateral strain gages calibrated utilizing on-track spreader calibration fixture
    4. Calibration Loading Procedure:
    5. Apply steadily increasing vertical then lateral load to maximum L/V of 0.5
    6. Record input lateral force and lateral strain gage outputs at 10 evenly spaced discrete points
    7. Create linear regression between lateral load and lateral circuit output (lbf/volt)
    8. Expected site-to-site variability: +/-20% lateral and +/-5% vertical

Instrumentation Services, Inc.
6547 N Academy Blvd #558
Colorado Springs, CO 80918 USA
Phone: [redacted]
e-mail: [redacted]

TPD Equipment Specification - Instrumentation and Data Acquisition Requirements

1. Data Acquisition System
    1. Rugged, industrial data collection computer
        1. -40 to 85 degC operating temperature
        2. Solid-state data storage
    2. A/D Conversion Specifications
        1. L/V strain gage data sampled at 500Hz to 2000Hz per channel, depending on typical train speeds
        2. 16-bit resolution
    3. Modular, isolated strain gage signal conditioning
        1. Fixed Excitation, Gain and Filter
        2. 10Vexc, 1000x gain, 120Hz anti-alias filter
    4. Automated Data Collection System
        1. requires no operator; un-attended operation
        2. Capable of remote system configuration, software maintenance, and data transfer
2. Power
    1. Low Power Consumption: total system continuous power draw typical < 15 Watts
    2. Data Acquisition system operates from DC 12V/24V, battery-backed power supply
    3. 120/240 VAC , 2-Amp max, required to power data system continuously. AC line connected to battery charger.
    4. In Lieu of AC power line availability, Solar Power option is possible

3. Data Communications
    1. Wireless, Cellular 4G data modem
    2. TCP/IP networking to Internet-Hosted Database

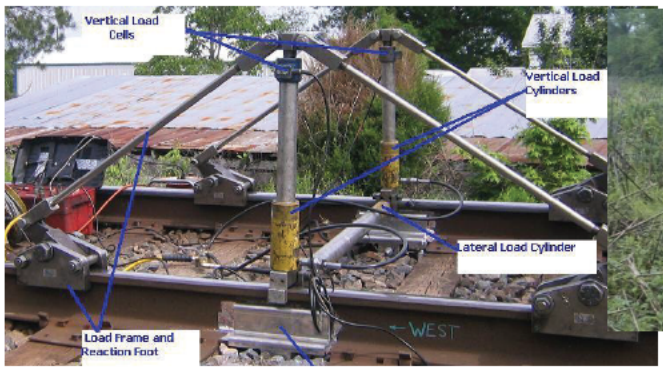
Instrumentation Services, Inc. • 6547 N Academy Blvd #558 • Colorado Springs, CO 80918 USA
719 [redacted] (office) • 719 [redacted] (fax) • [redacted] (email)

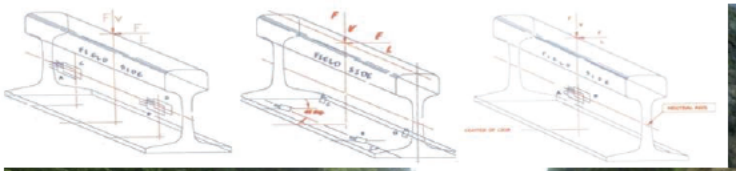
Instrumentation Services, Inc.
6547 N Academy Blvd #558
Colorado Springs, CO 80918 USA
Phone: [redacted]
Fax: 719 [redacted]
e-mail: [redacted]

ISI Qualifications and Experience

For more than 25 years, Instrumentation Services (ISI) has provided expertise in measurements of railroad wheel/rail performance. ISI installs the specialized strain-gage sensors, instrumentation hardware, and data collection equipment needed to make accurate assessment of static and dynamic railway and vehicle performance. Instrumentation Services utilizes its experienced in-house resources to support the entire project life cycle, from measurement-system design to reliable data delivery. ISI's qualified specialists are experienced working in the dynamic railroad environment, and understand the unique challenges associated with making accurate, quality measurements in a safe, efficient manner. L/V strain gages are inter-connected to data acquisition systems capable of reliably recording critical performance data, and specially designed to perform in the harsh railroad environment. ISI continually monitors the measurement-system health and promptly repairs equipment, ensuring quality data is delivered so that program managers can make timely, effective decisions.

Instrumentation Services has provided strain gage and railroad testing services in support of projects on test-tracks and laboratory equipment, short-line railroads, subway track, transit and freight railroads throughout the world, including all Class-I North American Railroads. ISI maintains a stellar safety record working in the dynamic railroad environment worldwide. ISI's employees are qualified to all railroad-specific clearances and track-worker safety programs.





Automatic Wayside Inspection System

Introduction to WMATA's Pilot AWIS

- Description and Capabilities

06 April 2022
Rev 01

WMATA AWIS Installation

- In early 2020, WMATA installed a WABTEC (Track IQ) automated wayside inspection system as a part of a pilot program.
- The installation is within Greenbelt Yard (E99), located between signals 62 and 42.
- This AWIS is composed of track mounted equipment (see photo to right)
  - Equipment enclosures
  - Cameras
  - Lasers
  - Sensors

WMATA AWIS Installation

- This AWIS is also composed of an electronic equipment locker and an AEI tag reader.

AWIS - Machine Vision Core System

- Integrated Video Capture Module
  - Multiple images of each wheel are taken. The images are high quality, produced using a CCD with an array of up to 1024 x 1024 active pixels. Because of the flash intensity and fast shutter speed, the system is independent of the ambient light – this means that the same result is achieved by day or night.
- Industrial Processing Units
  - The images undergo pre-processing in the IVCM before they are transferred to the processing server.
  - The unit is built with industrial grade hardware: capture server, database server, processing server and image processing clients, network switch, router, UPS, communication module (Fibre, DSL Modem or radio link) and power switch.
- Intelligent Wheel Sensors
  - The wheel sensors are positioned strategically to confidently record each wheel and measure the geometry of the bogies, cars, and the entire train from the first to the last axle.
  - Each wheel is tracked with precision when travelling over the system, and the image is taken in optimal timing. The Advanced Trigger Generating Unit ensures that camera and flash bulbs are properly synchronized for passing trains.

AWIS Machine Vision System

- Data accuracy is achieved through:
  - High-speed, high-resolution image capture units
  - Reference markers to calibrate every image
  - High-resolution digital images from our image capture units
  - Sophisticated machine vision algorithms that identify and measure vehicle components

AWIS Four Main Components

- WMATA's AWIS is comprised of four (4) main components, which work in tandem to provide data

1. Wheel Profile Monitor (WPM)
   - WPM takes multiple images of every wheel which are used to detect wheel wear and measure wheel profile parameters such as Flange Height, Width, and Angle, Rim Thickness (inner and outer side), Back-to-Back, Wheel Diameter, and Hollowing
2. Brake Inspection Monitor (BIM)
   - BIM inspects the brakes while in-service, measuring the remaining material in the pad and calculates a replacement window based on the historical wear rate. Alarms can be sent for critical events via email or other methods.
3. Bogie (truck) Geometry Monitor (BGM)
   - BGM measures truck geometry using inductive wheel sensors mounted on the rail.
4. FleetONE
   - FleetONE is the data management system that integrates condition monitoring data from the above range of wayside measurement devices. As a data integration platform, FleetONE can provide views of vehicles or components (e.g. a wheel, bearing or bogie/truck) that show all relevant measurements in one place.

AWIS Wheel Profile Monitor

- The Wheel Profile Monitor (WPM) is the portion of the system which monitors rolling stock wheels to improve wheel maintenance management.
- The WPM takes multiple images of every wheel which are used to detect wheel wear and measure wheel profile parameters such as Flange Height, Width, and Angle, Rim Thickness (inner and outer side), Back-to-Back, Wheel Diameter, and Hollowing.
- Images of each individual wheel are stored in the database and can be accessed as required for more detailed analysis.
- As the WPM system measures every single wheel with reference to its location on a particular vehicle, a trending of parameters is used to predict wear time and calculate wheel wear rate.

AWIS Wheel Profile Monitor

- The Wheel Profile Monitor (WPM) System Specifications
  - The parameters measured with the accuracy specifications are show in the table below.

Module	Function	Accuracy/Tolerance
Wheel Profile Monitor	Flange Width	±0.5 mm
	Flange height	±0.5 mm
	Wheel diameter	±2.0 mm
	Hollowing	±0.5 mm
	Back to Back dimension	±0.5 mm
	Inner rim thickness	±0.7 mm
	Outer rim thickness	±0.7 mm

AWIS Brake Inspection Monitor

- The Brake Inspection Monitor (BIM) is the portion of the system which monitors rolling stock brake discs and pads
- This system inspects the brakes while in-service, measuring the remaining material in the pad and calculates a replacement window based on the historical wear rate. Alarms can be sent for critical events via email or other methods.
- The BIM is configured as a bi-directional system with images taken as the train approaches the front of the lenses or as it departs the site.
- The images of each individual brake pad are stored in the database and can be access as required for more detailed data analysis condition and wear rates.
- If a critical defect is identified, such as a missing composite brake pad an alarm can be sent to initiate the appropriate action.

AWIS Bogie (Truck) Geometry Monitor

- The Truck/Bogie Geometry Monitor (BGM) system measures truck geometry using inductive wheel sensors mounted on the rail. This multi-functional system monitors or measures the following bogie parameters:
  - hunting of axles, trucks, and wagons (only available at mainline speeds)
  - angle of attack
  - tracking of wheelsets
  - distances between axles, trucks, and cars. These measurements are used to detect the following:
    - detecting failing draft gear or problems with coupling gear.
    - detecting cars which have pulled off the truck from the center of truck bolster beams.
    - detecting inter-axle misalignments and development of looseness in the side frame - due to problems with bearing adapters
    - axles that are permanently canted

AWIS Bogie (Truck) Geometry Monitor

- The Bogie Geometry (BMG) System Specifications
  - The parameters measured with the accuracy specifications are show in the table below.

Module	Function	Accuracy/Tolerance
Hunting/Tracking/Bogie Geometry Module	Lateral acceleration	+/- 0.1 g's
	Axle spacing	+/- 2.0 mm
	Angle of Attack	+/- 1.0 mrads

AWIS Data Management & Visualization - FleetONE

- FleetONE system is a data management system that integrates condition monitoring data from a range of wayside and on-board measurement devices. As a data integration platform, it is able to provide views of vehicles or components (e.g. a wheel, bearing or bogie/truck) showing all relevant measurements in one place

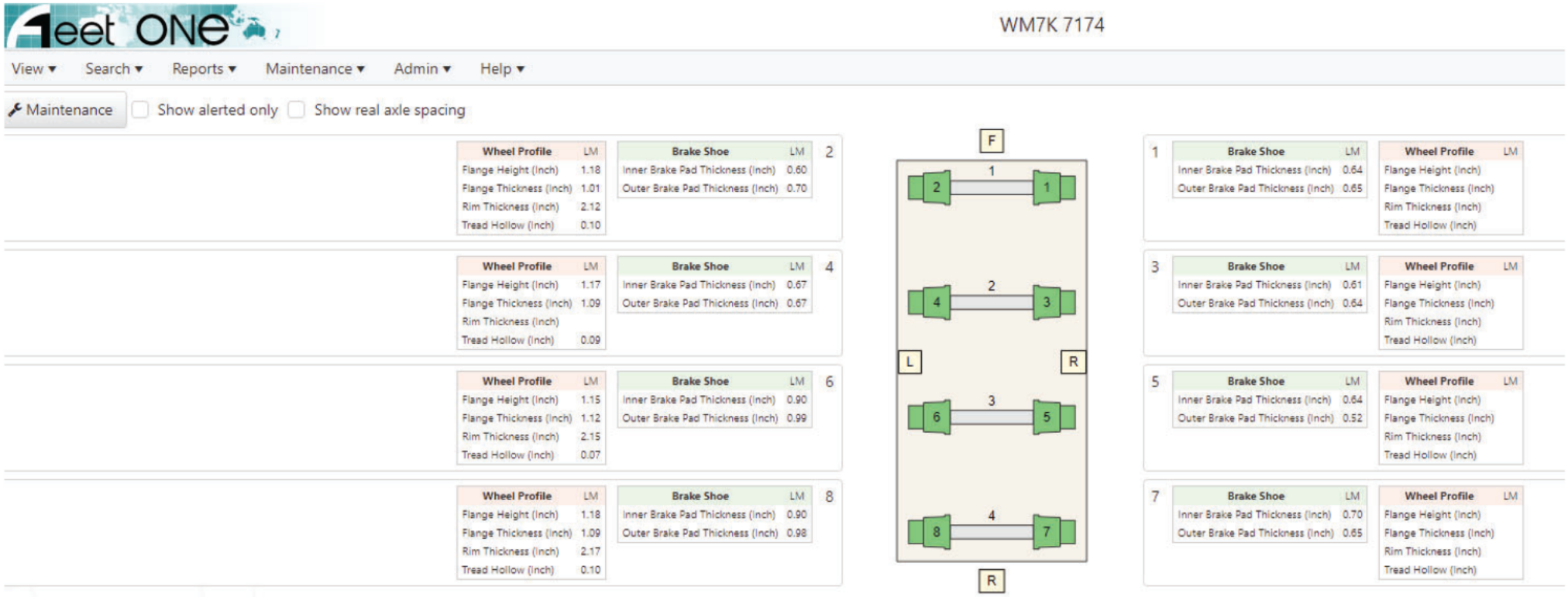
- FleetONE provides the ability to trend and graph any measurement parameter over time and to compose searches to retrieve condition information. Once composed, a search can be re-run at any time and emailed out as a scheduled report or alert.

AWIS Data Management & Visualization - FleetONE

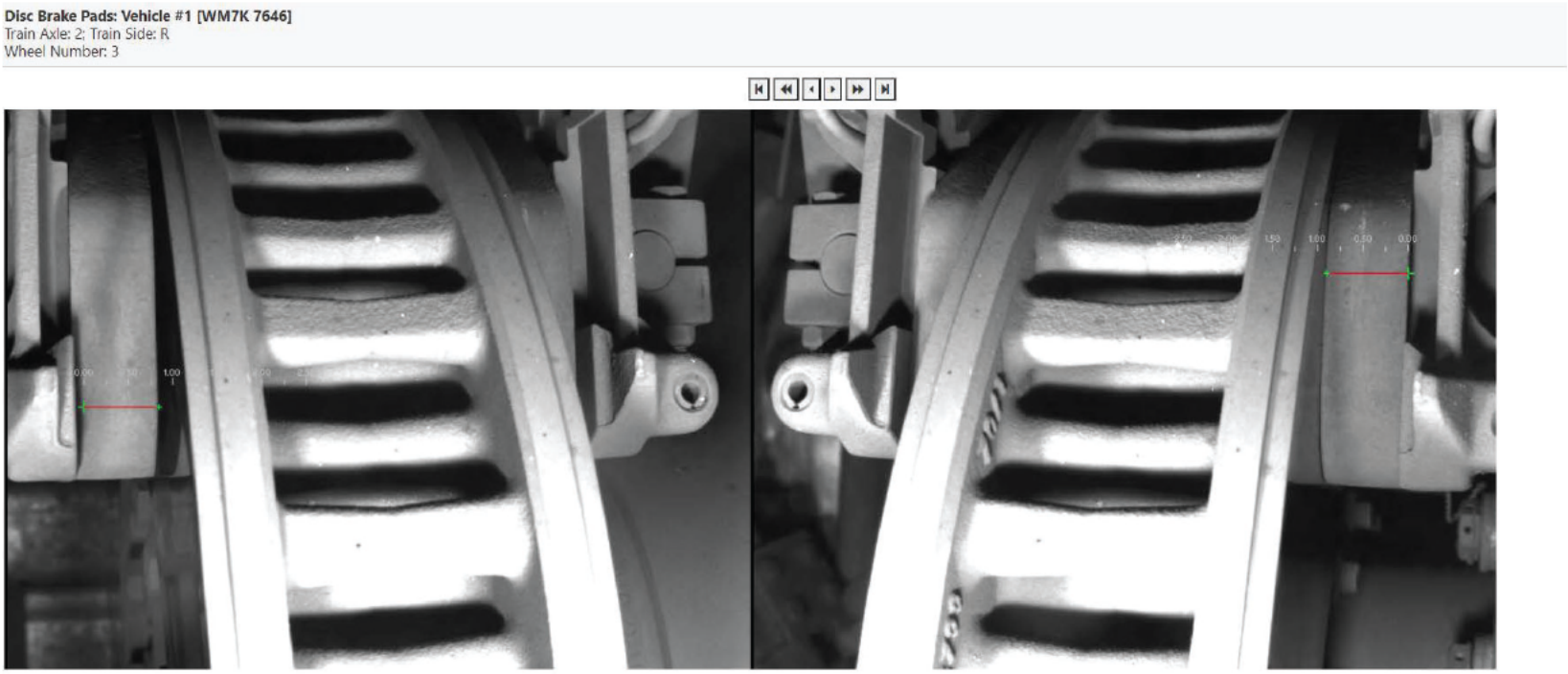
- FleetONE acts as a search engine
  - The search engine is an "ad-hoc" search builder that lets users create searches for any criteria (time range, measurement value, vehicle class)
  - The search engine provides capabilities that allow searches to trend data for a component (identified by vehicle AEI tag or train consist) over time, by providing "count", "average", "min" and "max" operations.

- FleetONE Automation – Maintenance System Integration
  - FleetONE integrates with maintenance systems (e.g. SAP, Maximo, Mincom, etc.).
  - Work orders to replace defective components can be automatically output at the click of a button.
  - Furthermore, completed work is input into FleetONE for display and serviced components are excluded from future search results.

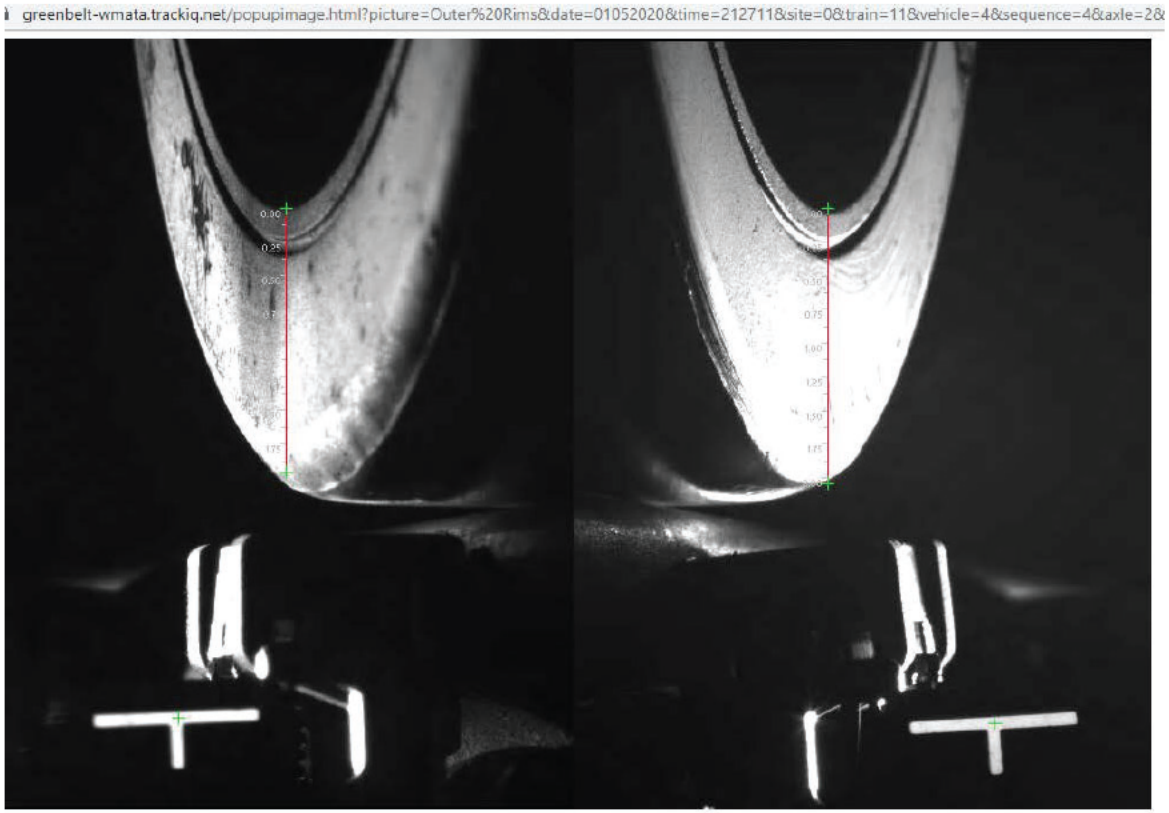
AWIS Data Management & Visualization - FleetONE



AWIS Data Management & Visualization - FleetONE

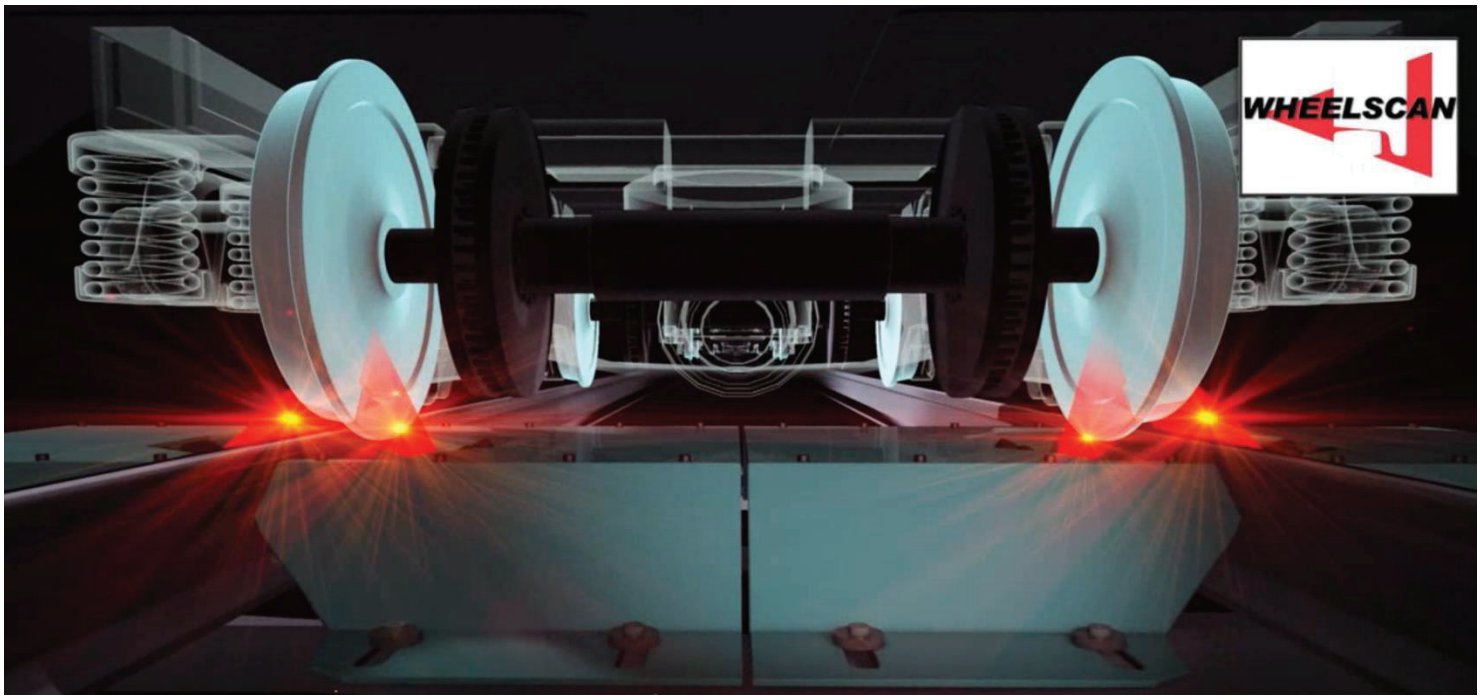


AWIS FleetONE Digital Image Examples



AWIS FleetONE Digital Image Examples

AWIS FleetONE Digital Image Examples



Technical Information on the WheelScan System

Prepared for

WMATA

Prepared by

KLD LABS
MEASUREMENT TECHNOLOGIES

55 Cabot Court, Hauppauge, NY 11788

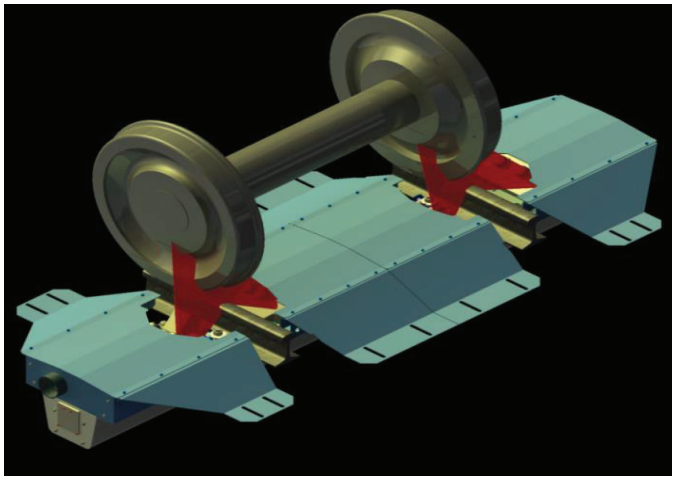
WheelScan Wheel Profile Measurement System

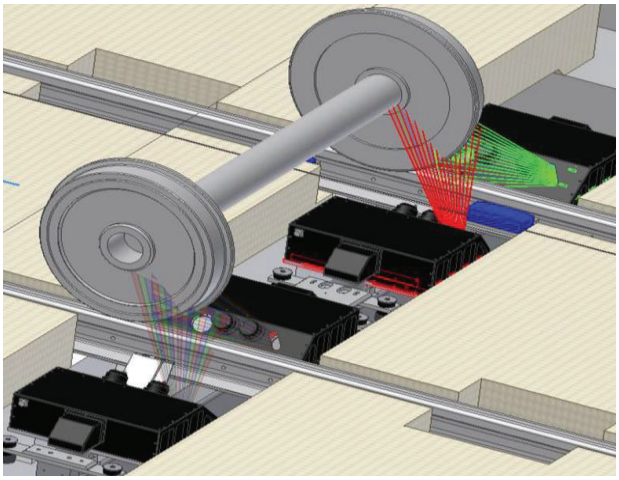
The WheelScan is KLD's flagship in-track wheel profile and wheel wear measurement system. The system can be installed outdoor in mainline track, yards or inside a depot/workshop.

Typical WheelScan Outdoor Installation

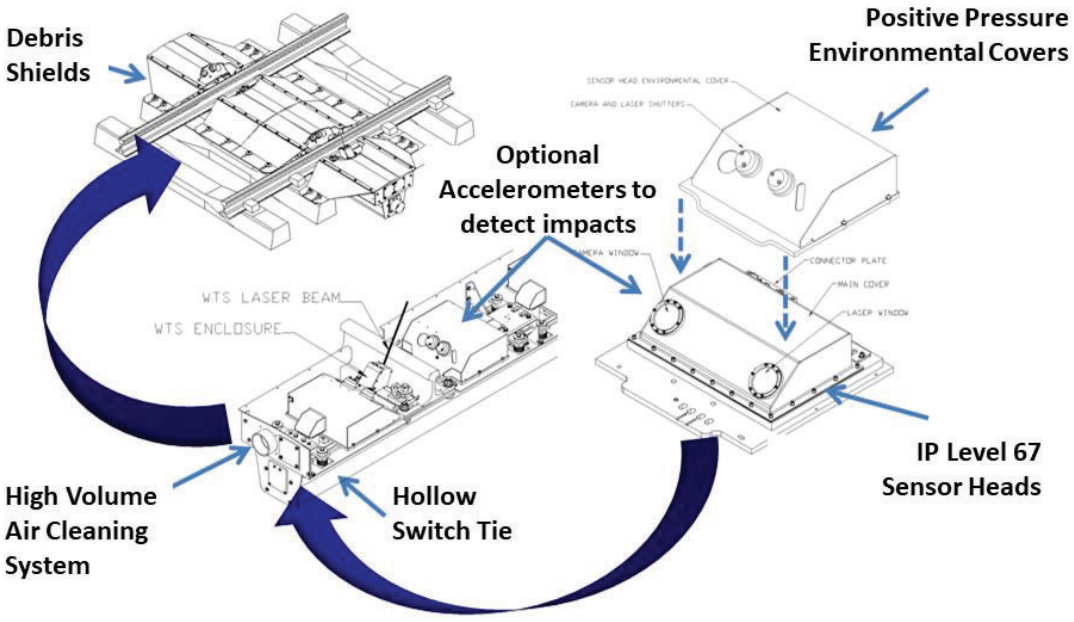
Typical WheelScan Indoor Installation

Utilizing a combination of lasers and high-resolution cameras the WheelScan system automatically acquires wheel profiles and wheel wear measurements at speeds up to 80 mph (130 km/h). Each sensor is housed in IP 67 environmentally controlled enclosures to ensure protection from the elements and the harsh railway environment.





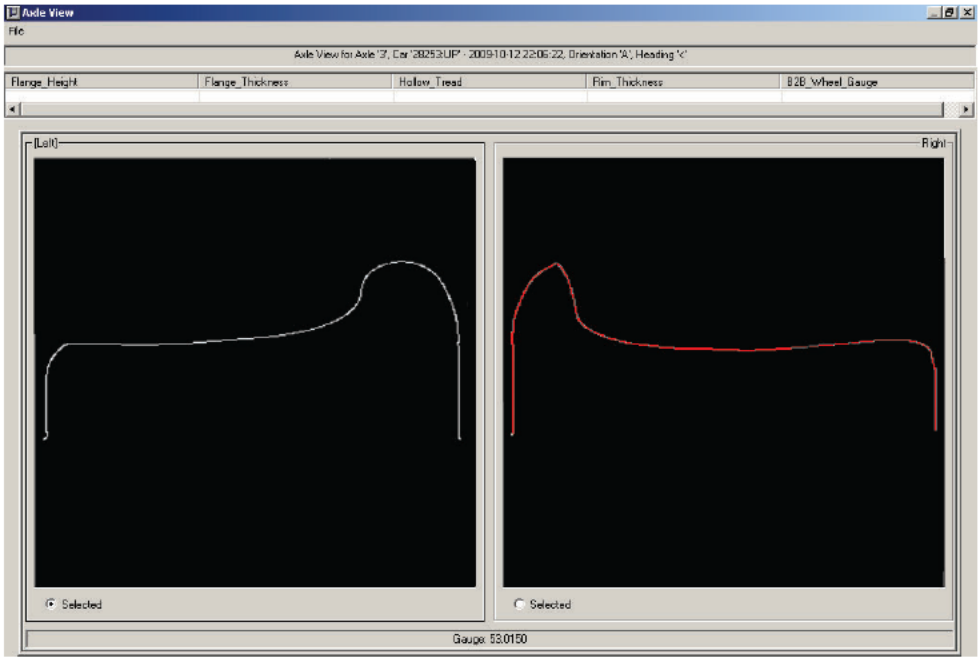
The WheelScan system offers 4 levels of protection, see below. The hollow switch tie offers a solid mounting system to attach the sensor heads and to protect the cables and high-volume air piping. The sensor heads are then protected by Environment cover which protects the optical windows and offer another level of protection to the cameras and lasers. Covering all of the sensor is another protection layer called Debris Shields. The Debris Shields are used to deflect any debris, snow and dragging equipment. KLD also offers, as an option, accelerometers installed in the sensors to detect impacts from dragging equipment.



The system is normally in a sleep mode until a train is detected. When this occurs the high-volume blowers are enabled and the environmental covers open the shutters that protect each optical window. The positive pressure developed by the blowers keep the optical windows clear. This protects them from the normal contamination (rain, snow, dirt and dust) found in the harsh railroad environment.

Typical WheelScan Site

Each wheel profile is acquired by the cameras and then key wheel wear measurements are made along with back-to-back gauge measurements.



Along with every measurement the system calculates, the WheelScan system incorporates the axle number and the vehicle identification information. This signal is either provided by the customer or can be provided by KLD. Once the train has completely passed, the axle, wheel and vehicle information are collated and consolidated into a "train consist" file which is transferred to KLD's TrainBase fleet management database and/or any customer management systems (Maximo, SAP, Trapeze, etc.). Once completed, the system re-enters a sleep mode and awaits the next train to measure.

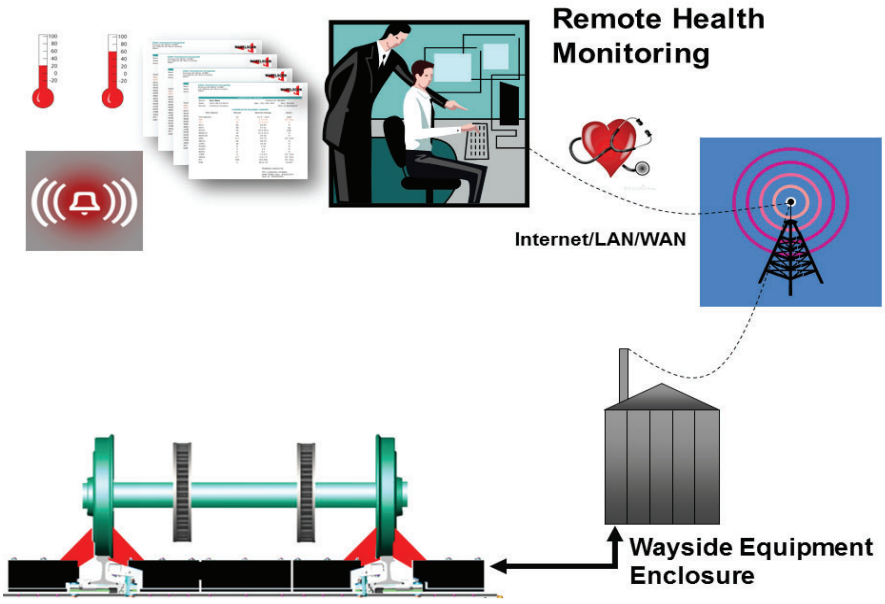
WheelScan Measurements include (1sigma):

- Wheel Profile +/- 0.25mm
- Flange Height +/- 0.5mm
- Flange Width +/- 0.5mm
- Flange Radius +/- 0.5mm
- Rim Thickness*/Diameter* +/- 0.5mm/+/-1.5mm
- Hollow Tread +/- 0.5mm
- Back-to-Back +/- 0.8* to 1.0mm
- False Flange/Tread Rollover +/- 0.5mm

*Measurements require high tolerance wheels/reference groove on wheel

Diagnostics and Health Monitoring

It is important to know that all of KLD systems are functioning properly. System within each of our sensor heads, electronics and computers are environmental monitoring sensors. These sensors provide continuous monitoring and alerting capabilities and enable remote monitoring and diagnostics by our customers as well as KLD service teams.

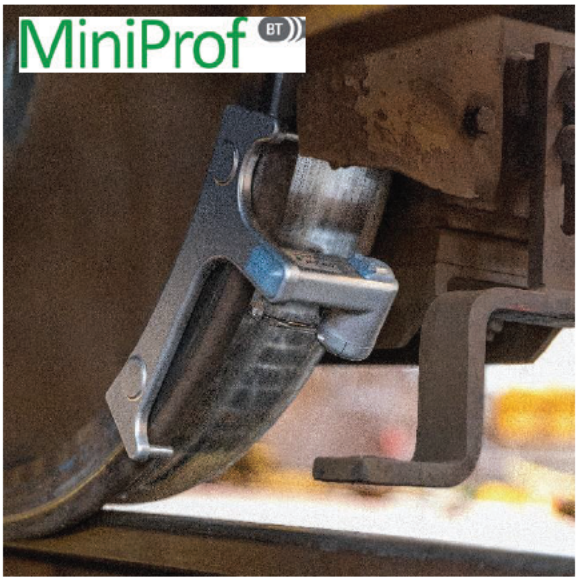


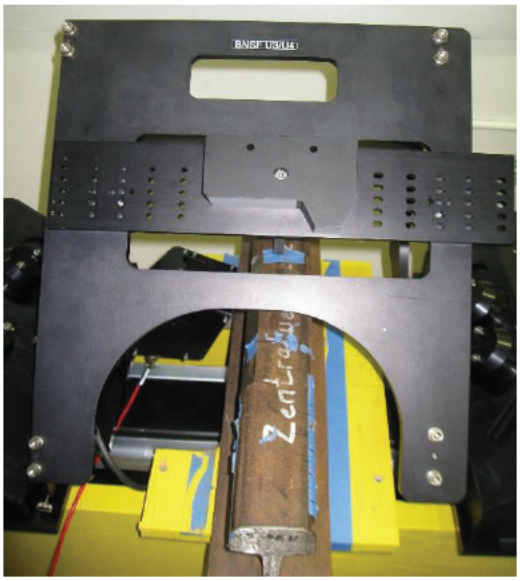
This WheelScan system captures a Status of System (SOS) Report each day, which also flags if maintenance is required. All of these parameters are regularly monitored by KLD and can also be forwarded to the Customer. Typical parameters monitored are:

- Laser Temperature/Alarm
- Sensor Head Temperature/Alarm
- Sensor Head Humidity/Alarm
- Sensor Head Mount Temperature
- Sensor Head Shock/Alarm
- CPU Temperature/Alarm
- System Heartbeat Status
- Fan Blower Current (for outdoor installations)
- Thermo-electric cooler Status
- Heater Power Status
- Laser Power Status
- Electronics Ambient Temperature/Alarm

System Validation and Calibration

During all WheelScan projects KLD provides comprehensive Factory Acceptance Tests and Site Acceptance Tests. During these tests the systems are calibrated and verified. KLD uses both high tolerance NIST traceable calibration fixtures along with portable full contact measurement tools (MiniProf) for validation.



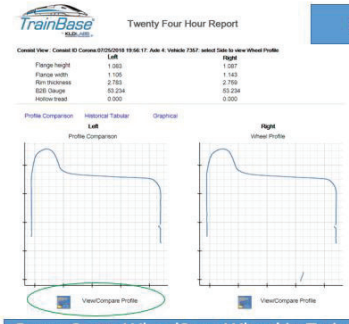


Going forward KLD recommends calibration on an annual basis and validation quarterly. To accomplish this task the system's accuracy can be easily verified for accuracy between calibrations with a MiniProf Wheel Profilometer. KLD developed this validation procedure to be able to check

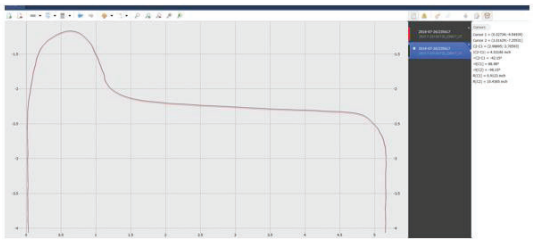
the WheelScan accuracy for seasonal changes or when an event occurs; for example, if the system had sustained an impact from some event. In this situation, it could be quickly verified whether or not calibration had been impacted. To accomplish this task, you simply export any WheelScan profile measurement into the MiniProf analysis software using TrainBase and comparing it to an independently collected MiniProf measurement of the same wheel.

Back-to Back calibration can also be verified using the MiniProf Twinhead Unit that connects directly to the wheelset. Examples of the verification process and the MiniProf equipment are shown below.

Collect any Wheel with the Wheel MiniProf

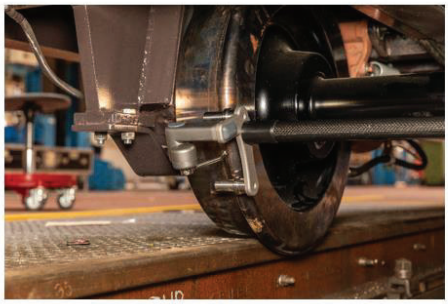


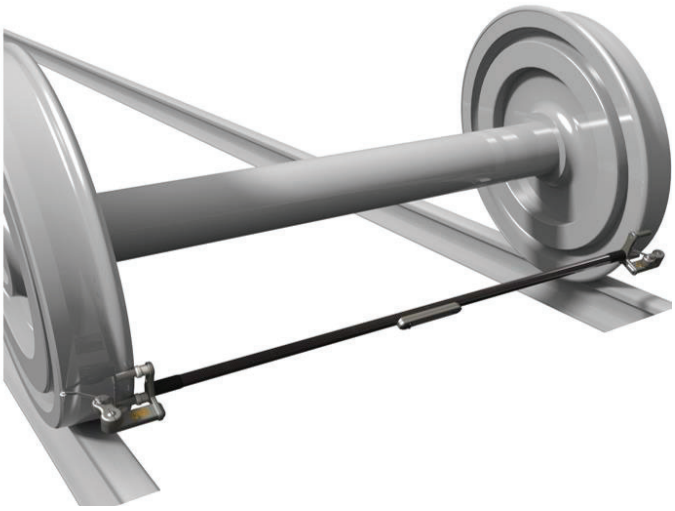
Query Same WheelScan Wheel in TrainBase & Single Click to Export Wheel to MiniProf



Overlay Exported WheelScan and MiniProf Wheel to Verify Calibration

MiniProf TwinHead

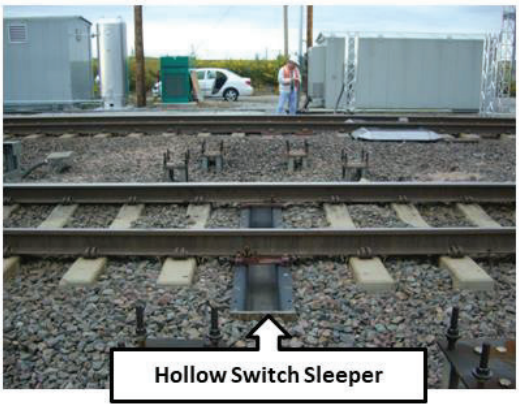


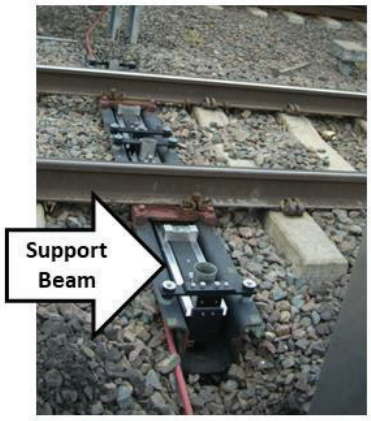


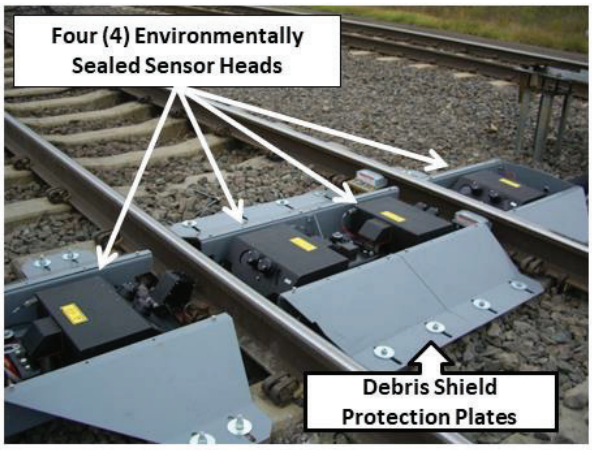
Outdoor WheelScan Installations

KLD 's WheelScan Wheel Profile Measurement System has been designed to be installed with minimal disruption to a railway's normal operation. KLD typically installs outdoor systems in ballasted track with the replacement of a single tie with a hollow switch tie and installation of a wayside bungalow or compact equipment enclosure.

The WheelScan is vibration isolated and suspended within a hollow switch tie. This design both protects the system as well as allows it to vertically move with the track. The hollow switch tie and sensor head mounting fixes the geometry of the sensor to ensures that a constant optical geometry is continuously maintained and maximizes the WheelScan system's performance.

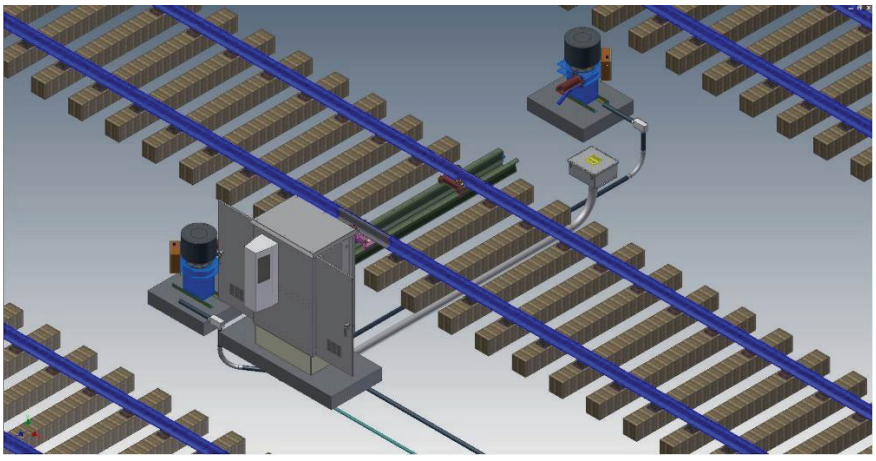


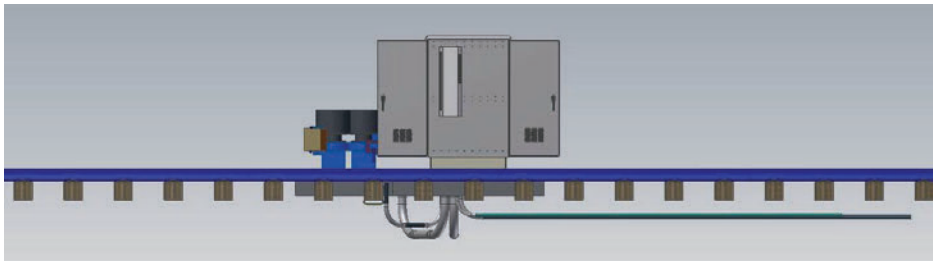




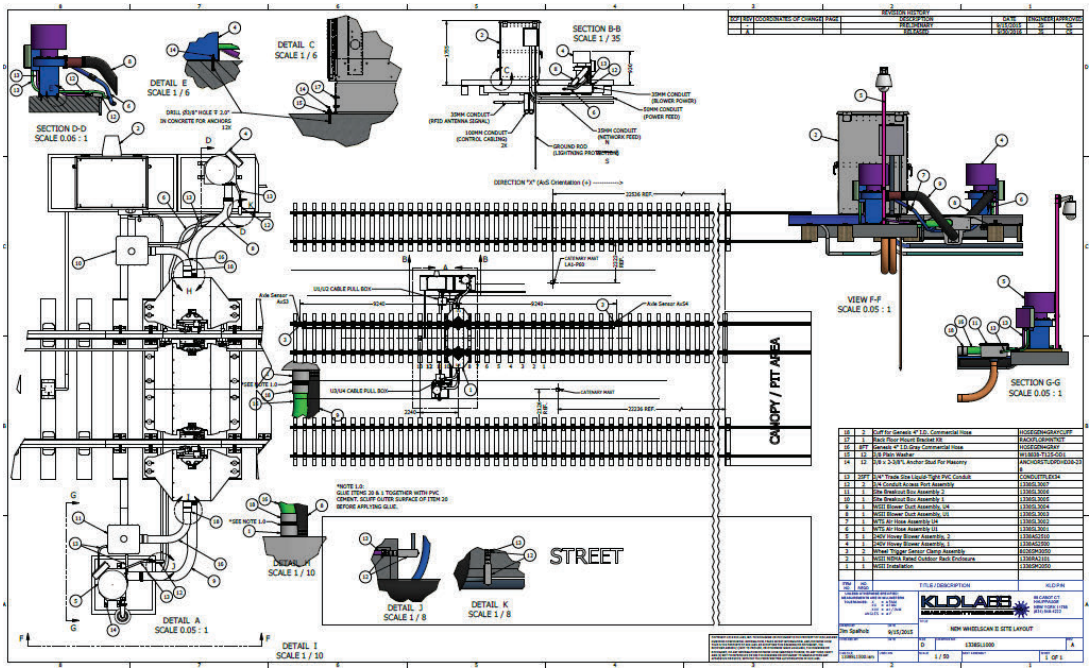
To maximize the system availability, KLD installs high volume blowers on all its outdoor installations. This maintains clear optical pathways. The type/size of the blowers installed are based upon individual site requirements. In excessive cold and hot weather climates, KLD can also offers an extreme weather package options that adds in-line heaters/coolers that work in conjunction with its blowers. The WheelScan installation process, along with typical blowers, are shown below.

While we do not have any specific information on the installation site for WMATA's requirement, other than some rough GPS coordinates, we have proposed an installation that is similar to one we currently have designed that can work well in areas with limited clearances. This installation approach employs a climate-controlled equipment enclosure that serves as both the electronics rack and protection for the electronics. This is in contrast to the standard climate-controlled bungalow we also use in which you install an equipment rack. It does not require a large pad, has minimal infrastructure impact and can be put in areas where space may be limited. This approach is being used for a commuter rail in Brazil, NYCT in the Corona Yard and other locations. The illustration below shows a typical layout for such an approach. Typically, one dedicated enclosure is required for each measurement system at the site. The actual trackside climate-controlled enclosure is shown as well.





A representative site drawing of a WheelScan employing this standalone trackside climate-controlled equipment enclosure is shown below.



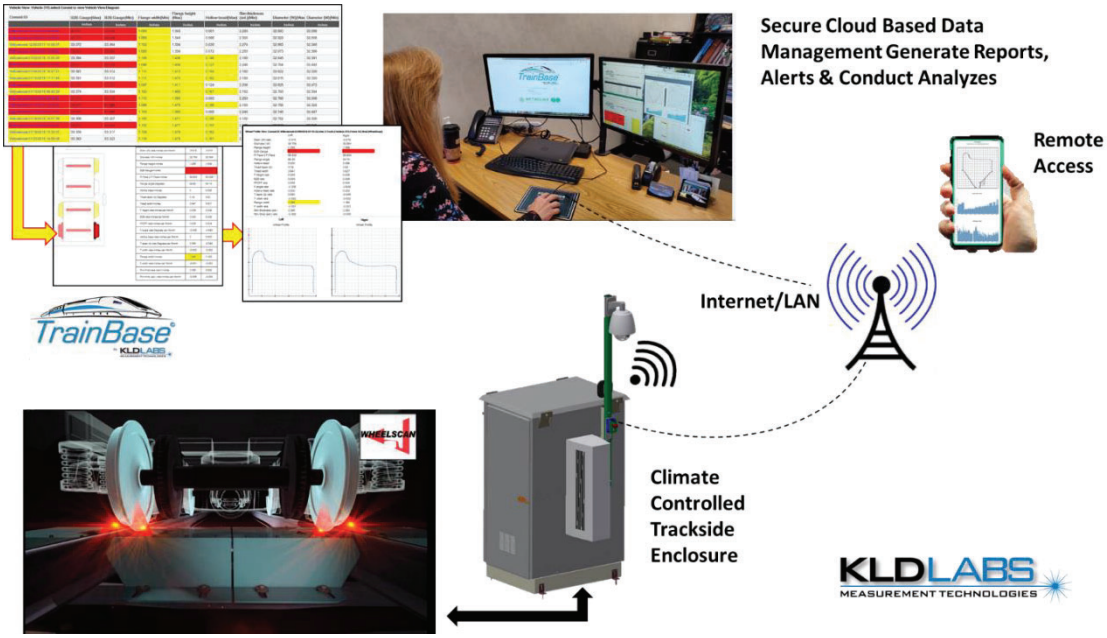
Site Improvements

Site locations will need to be updated to support the current system. Infrastructure improvements and other supporting tasks should be performed by WMATA for each of the sites. Infrastructure should be designed to support expansion of each site for additional measurement and inspection systems. The customer provided work effort typically includes:

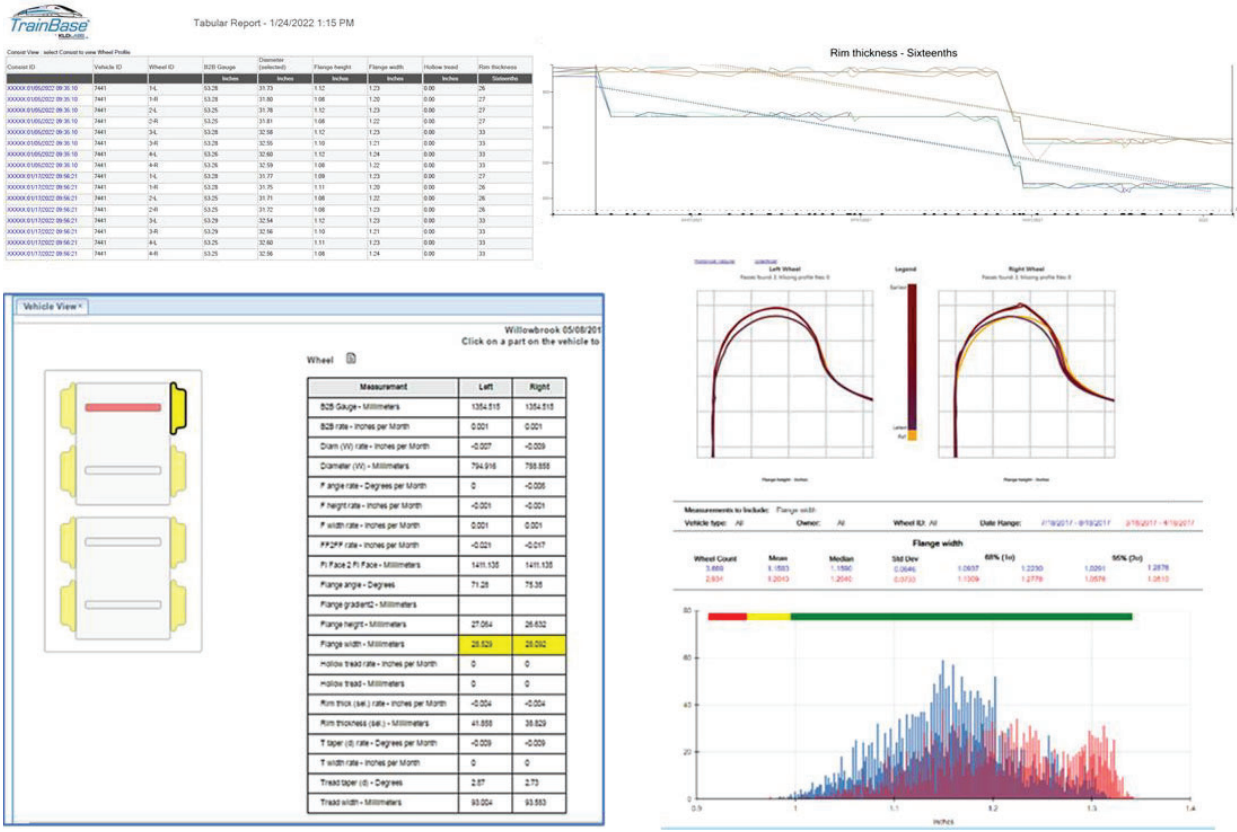
- All infrastructure work to accept the systems
  - Including but not limited to removal/installation of KLD supplied hollow switch tie
  - Conduits where needed
  - Concrete pads for equipment racks and instrumentation
  - Provide Power/Connections where needed
  - High Speed Communications for Data transfer with unrestricted access
  - Required track work where needed
- Supply of technical information on the site, vehicles, current RFID
- The RFID systems complies with AAR S-918a standard
- Receipt of Equipment, Storage, Transfer to Site and Positioning of Equipment
- Disposal of any shipping containers
- Supply of any required permits
- Provide the necessary track access and safety training as required

TrainBase – Fleet Management Database/Analysis

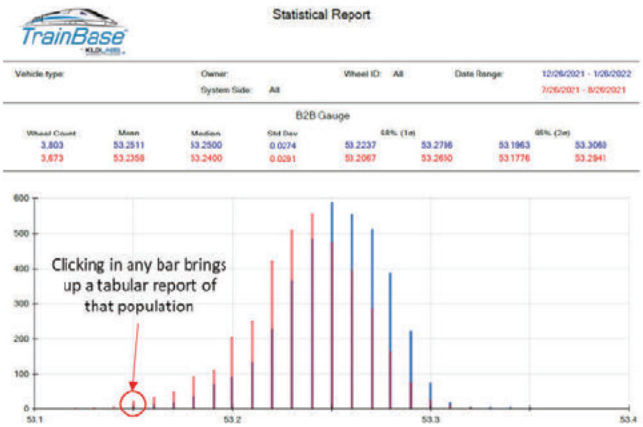
Data Management is provided through KLD's application TrainBase which is integrated with an MS SQL database and delivered via the Cloud. Initially developed for GO Transit commuter rail in Toronto in 2011 is has been continually improved supporting a wide range of rolling stock including the Amtrak's Acela high speed train, NYCT subway trains, as well as various streetcars, trams, light rail vehicles and freight. The user interface (IU) is a standard web browser that provides access from any Internet connected PC secured by a user ID and password. No software need be loaded on the PC. TrainBase tools allow users to set exception limits; to generate tabular, graphical, and statistical reports; to send email and SMS text-based alerts; to perform fleet analyses, trend wear, and run predictive maintenance reports; to overlay wheel profiles and graphically view the condition of an individual vehicle or an entire train consist. Data can be displayed tabularly or graphically by fleet, vehicle, axle and wheel.

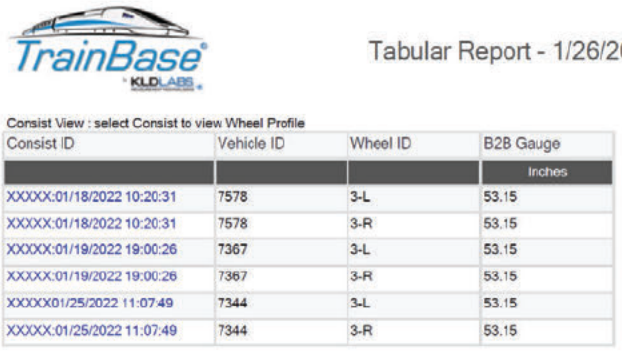


Data Management is provided through KLD's application TrainBase is integrated with an MS SQL database and delivered to the Customer via the Cloud. Initially developed for GO Transit in Toronto in 2011 is has been continually improved supporting a wide range of rolling stock including the Amtrak's Acela high speed train to Toronto streetcars. The user interface (IU) is a standard web browser providing access from any Internet connected PC secured by a user ID and password. No software need be loaded on the PC. TrainBase tools allow users to set exception limits; to generate tabular, graphical, and statistical reports; to send email and SMS text-based alerts; to perform fleet analyses, trend wear, and run predictive maintenance reports; to overlay wheel profiles and graphically view the condition of an individual vehicle or an entire train consist. Data can be displayed tabularly or graphically by fleet, vehicle, axle and wheel.



Examples of Tabular, Graphical, Vehicle View, Profile Comparison and Statistical Reports





Fleet Back-to-Back (B2B) Statistical Report Comparing 7/26/2021 to 12/26/2021

All KLD Labs' machine vision systems collect large volumes of images and measurement data. WheelScan is no exception and managing "Big Data" however requires an all-inclusive solution. TrainBase is an intelligent interface that is easy to use and provides comprehensive tools to analyze, format and report what is important to the user. The Cloud based solution supports all KLD in-track and wayside system (WheelScan, BrakeScan, CouplerScan and others). The password protected and multi-level user rights capable software application is accessed via a standard web browser and it is integrated with a fully scalable backend MS SQL database The advent of high-speed communication networks and the Internet also allows these to be located virtually anywhere.

TrainBase allows the user to configure wear limits and setup automated email notifications and statistical report generation. Additionally, data can be exported to 3rd party applications as well as enterprise asset management (EAM) software systems (SAP, Maximo, Trapeze, MiniProf, etc.).

TrainBase enables users to quickly "drill down" through the database by clicking on a vehicle, wheel, brake, or other machine vision measured component. The application is very flexible and can generate individual vehicle or fleet-wide tabular, graphical, statistical, trending and predictive maintenance reports. These reports can be exported in numerous formats including PDF, XPS Document, TIFF file, DXF, WHL and CSV. Reports can be filtered by time, vehicle, bogie, axle, or wheel. Scheduling and routing of all reports or the setup of email or SMS text alerts can be easily performed over the Web by authorized users.

TrainBase also provides valuable planning tools as in the Predictive Maintenance Report that has been shown below. This helps railway Mechanical Department staffs to better plan maintenance activities and to be proactive. In this instance the report has been generated based on flange thickness. TrainBase can generate these reports by vehicle ID, location, owner or by the date that rolling stock will need to be scheduled for maintenance.

Predictive Report: Prediction Count 32

Vehicle ID	Part Location	Measurement Type	Exception Date	Profile Comparison
6213	Truck 2 - Axle 2 - Left	Flange thickness	06/29/2021	
1321	Truck 2 - Axle 1 - Left	Flange thickness	07/01/2021	
6540	Truck 2 - Axle 1 - Right	Flange thickness	07/01/2021	
6065	Truck 1 - Axle 1 - Left	Flange thickness	07/03/2021	
7204	Truck 1 - Axle 1 - Right	Rim thickness	07/04/2021	
5544	Truck 2 - Axle 1 - Left	Flange thickness	07/07/2021	
5564	Truck 2 - Axle 2 - Left	Flange thickness	07/08/2021	
5544	Truck 1 - Axle 2 - Right	Flange thickness	07/08/2021	
6070	Truck 1 - Axle 1 - Left	Rim thickness	07/10/2021	
7274	Truck 1 - Axle 1 - Right	Flange thickness	07/11/2021	
7716	Truck 2 - Axle 1 - Left	Flange thickness	07/14/2021	
5444	Truck 1 - Axle 2 - Left	Flange thickness	07/16/2021	
1391	Truck 2 - Axle 2 - Right	Flange thickness	07/17/2021	

Predictive Maintenance Report for Flange Thickness

Priority	Route	Line	Track	Nearest Station	Opposing Station	Chain Marker	Nearest Yard	Site Visit	Unit #	WMATA (PM's) Estimate	KLD (PM's) Estimate	Comments
1	Green/Yellow	E	1	E09	E10	610+50	E99	Y	1	1/May/2022	Q2 2022	Firm
2	Red	A	1	A14	A15	879+50	A99	Y	2	1/Jun/2022	Q3 2022	Firm, but does require Contractor's (& WMATA supporting DEPT'S) review & approval
3	Green	F	2	F10	F11	520+00	F99	Y	3	1/Jul/2022	Q3 2022	Firm, but does require Contractor's (& WMATA supporting DEPT'S) review & approval
4	Red	B	2	B06	B05	268+50	B99	Y	4	Oct/22	Q4 2022	Firm, but does require Contractor's (& WMATA supporting DEPT'S) review & approval
5	Orange	D	1 or 2	D11	D12	439+00	D99	Y	5	Dec/22	N/A (yet)	Initial site evaluation performed
5	Orange	D	1 or 2	D12	D13	503+00	D99	Y	5	Dec/22	N/A (yet)	Initial site evaluation performed
5	Orange	D	1 or 2	D12	D13	573+0	D99	Y	5	Dec/22	N/A (yet)	Initial site evaluation performed
5	Orange	D	2	D13	D12	575+75	D99	Y	5	Dec/22	N/A (yet)	Initial site evaluation performed Would require wall-mount , as location is under an overpass
6	Blue / Silver	G	1 or 2	G03	G04	482+00	G99	Y	6	Feb/23	N/A (yet)	Initial site evaluation performed

ALTERNATES (if needed):

6	Orange/Silver	K	?	K05	K06	?	K99	N	6	Feb/23	N/A (yet)	Exact site / track not confirmed. Initial site vist to occur on 08 April 2022.
6	Blue	J	?	J03	J02	?	J99	N	6	Feb/23	N/A (yet)	Exact site / track not confirmed Initial site vist to occur on 08 April 2022

TPD MAINTENANCE HISTORY

Location: GREENBELT YARD LEAD - Chain Marker: (YL1) 11+00		
Date	Type	Description
12/7/2004	Installation	Install L/V Gages on Rails, Data Collection Equipment, Calibrate L/V gages
1/13/2005	Installation	Install AEI Tag Reader
2/7/2005		Commissioned Data Service from TTCI/InteRRIS
9/2/2005	Repair	Replace 1 signal conditioner module and A/D converter card failed due to power surge. Install surge protection
8/28/2007	Repair	Replace power supply (battery charger)
9/10/2008	Repair	Replace damaged cable and strain gages Crib #3 caused by track maintenance equipment
9/10/2009	Calibration	Calibrate L/V gages
2005-2010	Repair	Several instances of phone line problems and upgrades
2008-2015	Repair	Several instances of power problems, AC power feed turned off, breaker disconnected, etc
3/16/2013	Repair	Computer replacement
3/16/2013	Calibration	Calibrate L/V gages
7/18/2014	Repair	Equipment upgrade replace computer 16ch A/D 3G Verizon Data Modem installed to replace land-line comms
7/29/2014	Repair	Software configuration fix for AEI tag failed reads
8/10/2014	Calibration	Calibrate L/V gages
2015	Installation	Solar panel installed to provide system power (AC power supply deemed unreliable)
1/15/2016	Out of service	Bad power wiring harness found
3/2016	Repair	Wiring harness repaired
7/9/2016	Calibration	Calibrate L/V gages
8/16/2016	Repair	Software adjustment to filter noisy data and discard partial train data. Angle of Attack (AoA) measurement set to zero / deprecated
5/28/2021	Out of Service	Last data report.
5/29/2021	Out of Service	Offline due to failed computer, failed power supply
4/23/2022	Repair & Calibration	Replace computer and power supply, upgrade 3G modem to 4G, calibrate L/V gages, verify reading of 7k tag, resume data service

Location: NEW CARROLTON Yard - Chain marker: (Lead Track 1) 16+60		
Date	Type	Description
10/15/2007	Installation	Install L/V Gages on Rails, AEI Tag Reader, Data Collection Equipment, Calibrate L/V gages
10/31/2007	Installation	Commissioned Data Service from TTCI/InteRRIS
9/11/2008	Calibration	Calibrate L/V gages
3/17/2013	Calibration	Calibrate L/V gages
8/9/2014	Repair	Equipment upgrade to replace computer 16ch A/D 3G Verizon Data Modem installed to replace land-line comms
8/9/2014	Calibration	Calibrate L/V gages
10/25/2015	Repair	Software update to recover from corrupted partition
7/10/2020	Calibration	Calibrate L/V gages
8/16/2016	Repair	Software adjustment to filter noisy data and discard partial train data. Angle of attack (AoA) measurement set to zero / deprecated
8/16/2016	Repair	Intermittent noise noted on LW01 - need fix at next calibration cycle
4/24/2022	Repair & Calibration	(Online and reporting data to ISI FTP site all 3 cribs L/V OK AEI Tag Reads OK) Verify reading of 7k tag, upgrade 3G modem to 4G, calibrate L/V gages, resume data service

AWIS MAINTENANCE HISTORY

Location 1: GREENBELT YARD LEAD - YL1 between signals 62 and 42 AWIS pilot installation		
		Pilot AWIS {Track IQ (WABTEC)}
Date	Type	Description
2/2020	Installation	Equipment installation without the lasers, as that equipment was not ready at the time of the installation.
3/2020	In Service	System functioning at reduced capability
11/2021	Installation	Exterior lasers installed and configured, with interior laser/camera remaining to be installed (bracket / fixation issue).
Ongoing/Upcoming work	Installation & Calibration	Installation of two interior lasers (enhance brake disc imaging/measurements), and completion of calibration of the pilot system over the upcoming 90 days.