


Equipment Performance Monitoring: Technology Driven Train Inspection

Technology Implementation Assessment

MARTS
Chicago
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Presentation Outline

- **Reference 2005 Discussion: various technologies**
- **Objective of TDTI: link to EHMS**
- **CFR Compliance**
- **Challenges, Attributes and Targets of Opportunity**
- **Wheel Profile System Status**
- **Brake System Status**
- **Advanced Inspection Systems**
  - Safety Appliances
  - Cracked or Damaged Components
- **Data (TDTI) to Information (EHMS) to Action**

Technology Driven Train Inspection (TDTI)

Vision

- **Satisfy inspection requirements of CFR 49 Parts 215, 231, and 232 with an integrated system of advanced sensor technology (machine vision, IR, laser ultrasonics, etc.)**
- **Use a combination of hardware, software and data assessment technology for performance based inspections to effectively replace the current inbound/outbound inspections performed by yard inspectors**
- **Provide data that can satisfy or enhance and replace manual inspection requirements (will likely require rule changes)**
- **Ultimately, significantly reduce number of personnel totally dedicated to train inspections: focus on corrective actions**

Objective:

- **To enhance the quality and efficiency of train safety inspection processes through applications of existing and advanced technologies …**
  - To utilize technology to replicate equivalent and wherever possible achieve enhanced levels of railway freight rolling stock inspections for safety compliance and performance
  - To utilize multiple detector systems, global data bases, and analyses in concert with compatible safety and operating rule and regulation changes for increased safety and productivity
  - To introduce performance based criteria as appropriate to enhance safety.

Current Requirements

- **All train inspections are specified in the Code of Federal Regulations (CFR) Title 49:**
  - Freight Car Safety Standards (Part 215)
  - Railroad Safety Appliance Standards (Part 231)
  - Brake Systems Safety Standards (Part 232)

- **Designated as pre-departure inspections**

Current Practices

- **For efficiency most railroads perform post arrival or inbound inspections**
  - Allows a yard or switching facility to locate and tag defective (Bad Order) cars prior to making up or blocking new trains
  - Bad ordered cars are switched directly to a repair track where repairs and subsequent inspections are made to remove and document the failed components
  - Practice prevents defective cars from being placed in a new train and then having to be switched out when the defects were discovered

- **Railroads ensure compliance with CFR49 regulations by conducting outbound inspections as well**

Desired TDTI System Attributes

- Easy installation
  - Minimal operational disruption
  - Minimal hindrance to maintenance operations
- Low maintenance requirements: simple, quick
- Long service life / durability: long MBTF
- Accurate, repeatable data
- Focused inspections for actionable maintenance
- Solid return on investment

"Better than Current Processes"

TDTI Challenges

- **ROI (Financial)**
- **Acceptance and Implementation (Policy, Philosophy)**
  - Compliance with Rules and Regulations
  - Compatibility with Operations
- **Vehicle Compliance Certification (Performance based)**
- **Monitoring Equipment Standards**
  - Reliability
  - Accuracy
  - Calibration Verification
  - Data Standardization
  - Certification
- **Data Accessibility**
  - Current
  - User Friendly Formats
  - Readily Available

Monitoring Systems: Examples

- **"Direct" Measure**
  - Dragging Equipment
  - Clearance
  - Hot Journal
  - Wheel Impact load
  - Overload/Imbalanced Load
  - Wheel Profile
  - Brake Shoe Condition
  - Spring Condition
  - Bearing Adapter
  - Coupler and Draft Gear
  - Safety Appliances
- **"Performance" Measure**
  - Acoustic Bearing
  - Hot/Cold Wheel
  - Truck Curving Performance
  - Truck Hunting
  - Acoustic Air Leak
- **Advanced Wayside Systems**
  - Cracked Wheel
  - Cracked Axle
  - Structural Damage

Monitoring Systems: Levels

- **Notifications**
  - Individual “Stand Alone” or Linked Systems
    - Individual Alarms
    - Trending Predictive Advisories
    - Human Assist / Interpretation
      - Semi-automated
      - Automated
      - Expert Systems
  - Multiple Systems through Central (Industry) Databases
  - Local or Internal Corporate Specific Databases

Monitoring Systems: Implementation Strategy

- **Systems Approach to Meeting CFR Regulations (Safety)**
  - Data integration
  - Multiple Systems
  - Accessible Databases
  - Intelligent Analyses
  - Intelligent Inquiry
- **Demonstrated Effectiveness (Efficiency)**
- **Maintenance Planning Assistance (Productivity)**
  - Trend Lines for Proactive or Opportunistic Maintenance
  - Expert Systems Guidance for Corrective Actions

Monitoring Systems: Implementation Strategy

- **Technology Search**
  - Existing Technologies
  - Adoptive Technologies
  - Adaptive Technologies
  - New Technologies
    - Safety Appliances
    - Broken, Loose Components
- **Phased Approach**
  - Gradual
  - Iterative
- **Technology Accommodation**
  - Interactive Rulemaking (AAR)
  - Regulation (FRA) Modification
  - Waivers for Trial Implementation

CFR Parts 215, 231, & 232 Overview

- 49 CFR part 215 -- Railroad Freight Car Safety Standards – contains approximately 140 inspection requirements.
- About 40 can be tested by systems currently in production or with further development of current systems.
- About 40 pertain to outdated equipment such as plain bearings, or to special circumstances such as bearings involved in derailments
- 14 requirements would be detected during the pre-departure inspection required by Appendix D to Part 215.
- Remaining requirements may well require legislative relief to provide alternate inspection criteria, or the development of advanced systems (e.g. car features database or equivalent to inspect safety appliances for individual car types)

CFR Parts 215, 231, & 232 Review

Regulation Modifications

- In some cases, the existing inspection requirement cannot be directly measured by an automated system.
- These requirements will require alternate performance-based criteria.
- Examples include:
  - 49 CFR 215.119(c) – location of side bearings is not conducive to machine vision inspection
  - 49 CFR 215.115(a)(2)(i) – loose end cap screw cannot be detected through non-contact inspection

CFR Parts 215, 231, & 232 Review

Procedural Issues

- **Current set of inspection criteria assumes a human inspector; some criteria are not directory applicable for automated inspection.**
  - **49 CFR 232.203 governs training and testing requirements of ‘qualified persons’ required for testing of brakes.**
  - **49 CFR 232.207(b)(2) requires that the inspector take ‘positions on each side of each car’ to inspect the brake system.**

Current TDTI Targets Of Opportunity

- **Wheel Data: flange height & thickness, rim thickness, and wheel hollow wear**
- **Brake System Data: brake shoe thickness, worn or missing brake heads, missing brake shoe keys, brake beam & slack adjuster conditions, hand brake position (on or off), and brake application & release verification**
- **Others measurements of interest:**
  - **Coupler and draft gear condition**
  - **Bearing adapter position / condition & spring nest condition**
  - **Sliding wheel detection, end cap bolt presence, & locking plate condition**
  - **Safety appliance position and condition**
  - **Grease leakage from cartridge journal bearings**
  - **Non-destructive evaluation of wheels and axles**

CFR Parts 215, 231, & 232: Wheels

Wheel Profile Module

- **Measures flange height, flange thickness, rim thickness, and back to back spacing.**
- **Satisfies FRA inspection requirements:**
  - **49 CFR 215.103(a) – flange thickness**
  - **49 CFR 215.103(b) – flange height**
  - **49 CFR 215.103(c) – rim thickness**
  - **49 CFR 215.103(e) – loose wheel (derived from back-to-back spacing)**

Wayside “Machine Vision” System

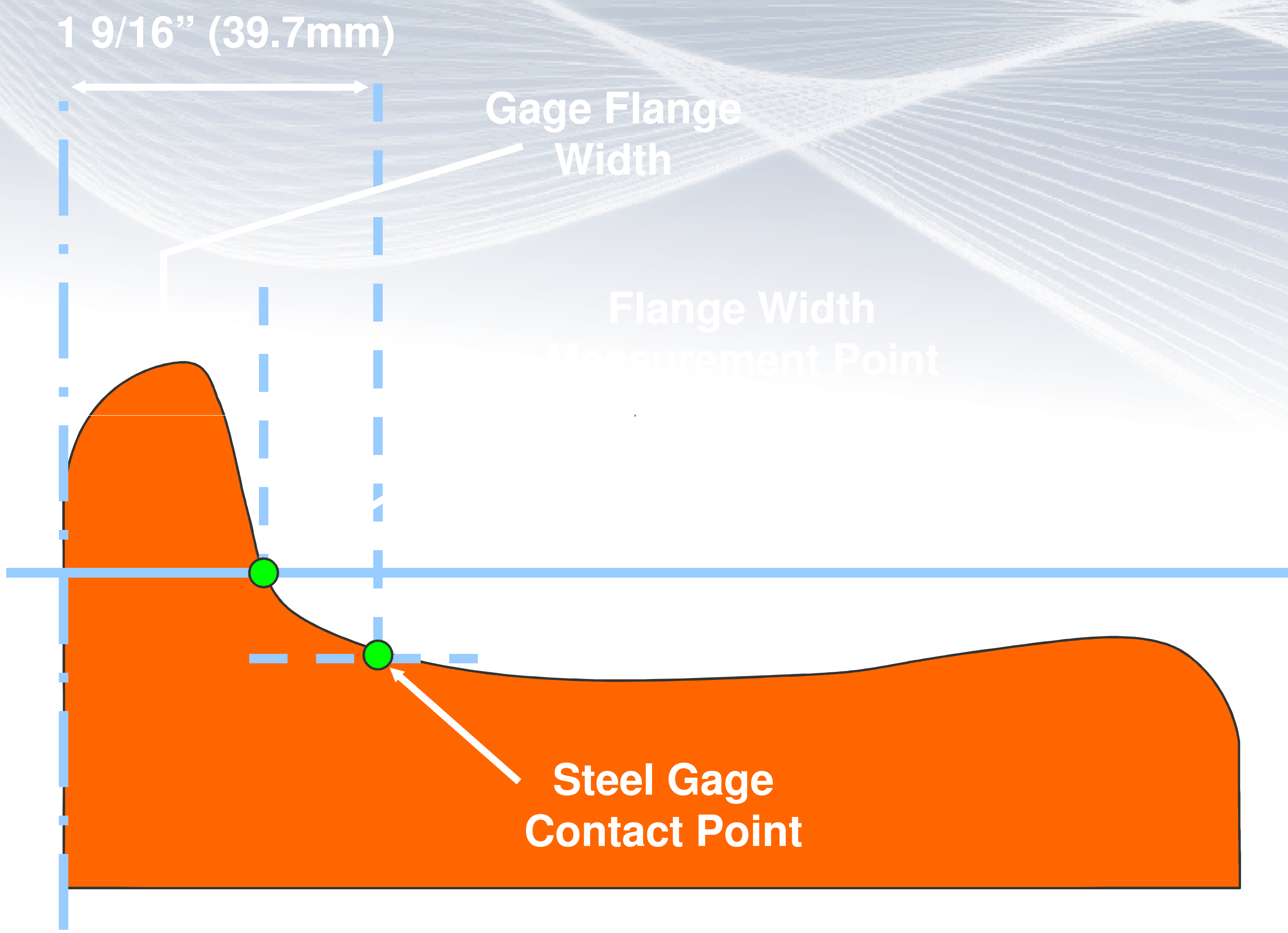
Wheel Profile Inspection

System Images

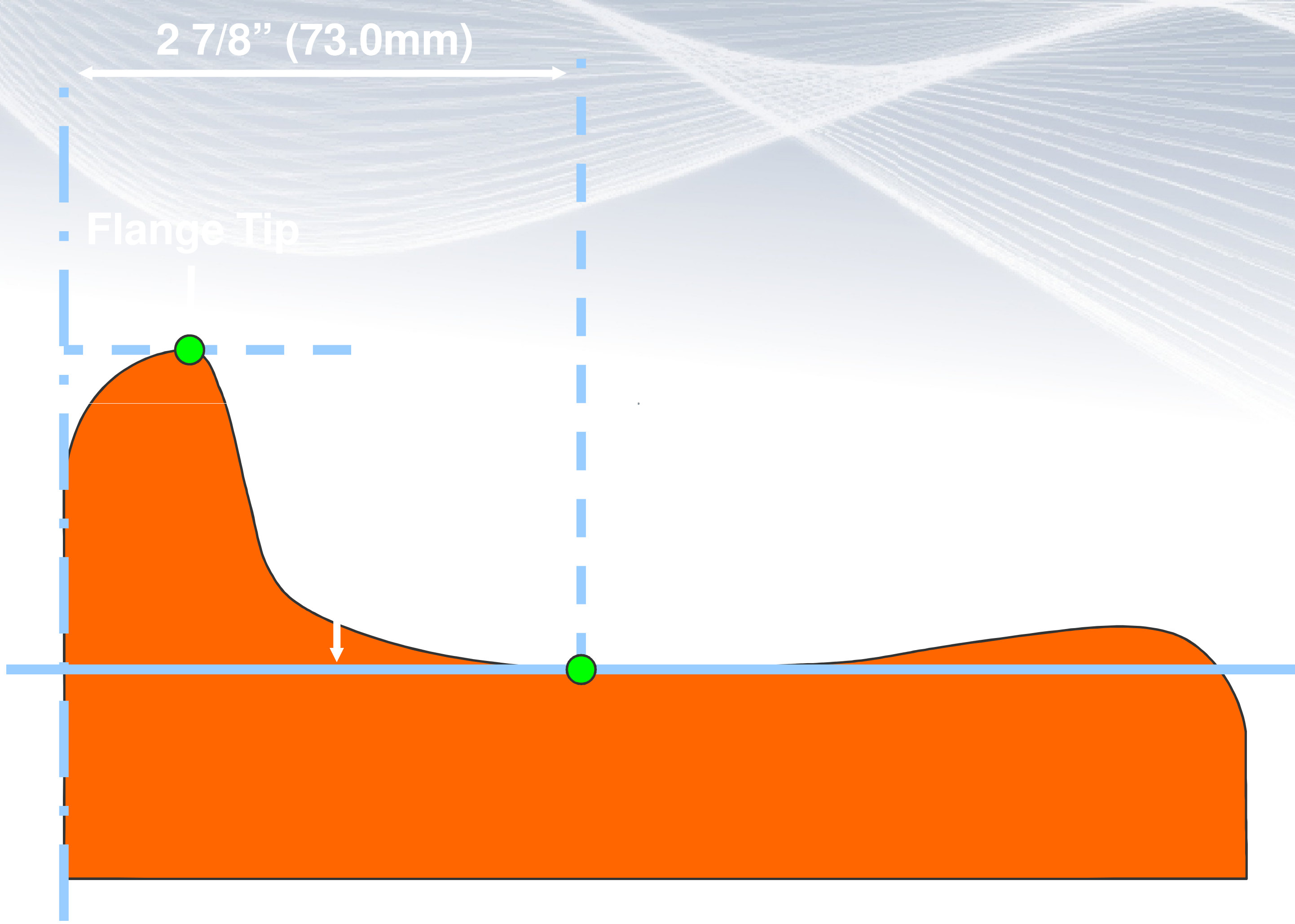
Rim View

Flange View

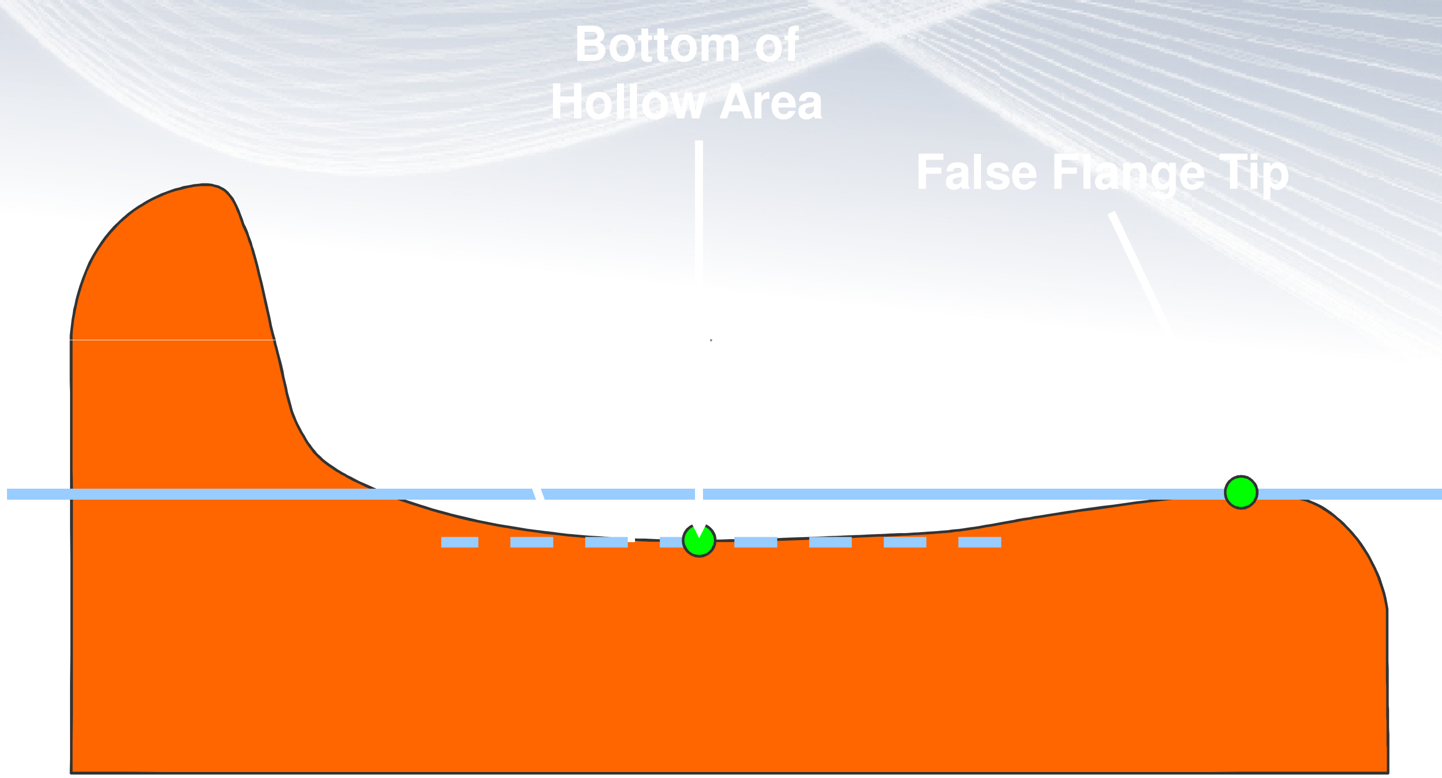
Flange Width – Steel Gage Equivalent



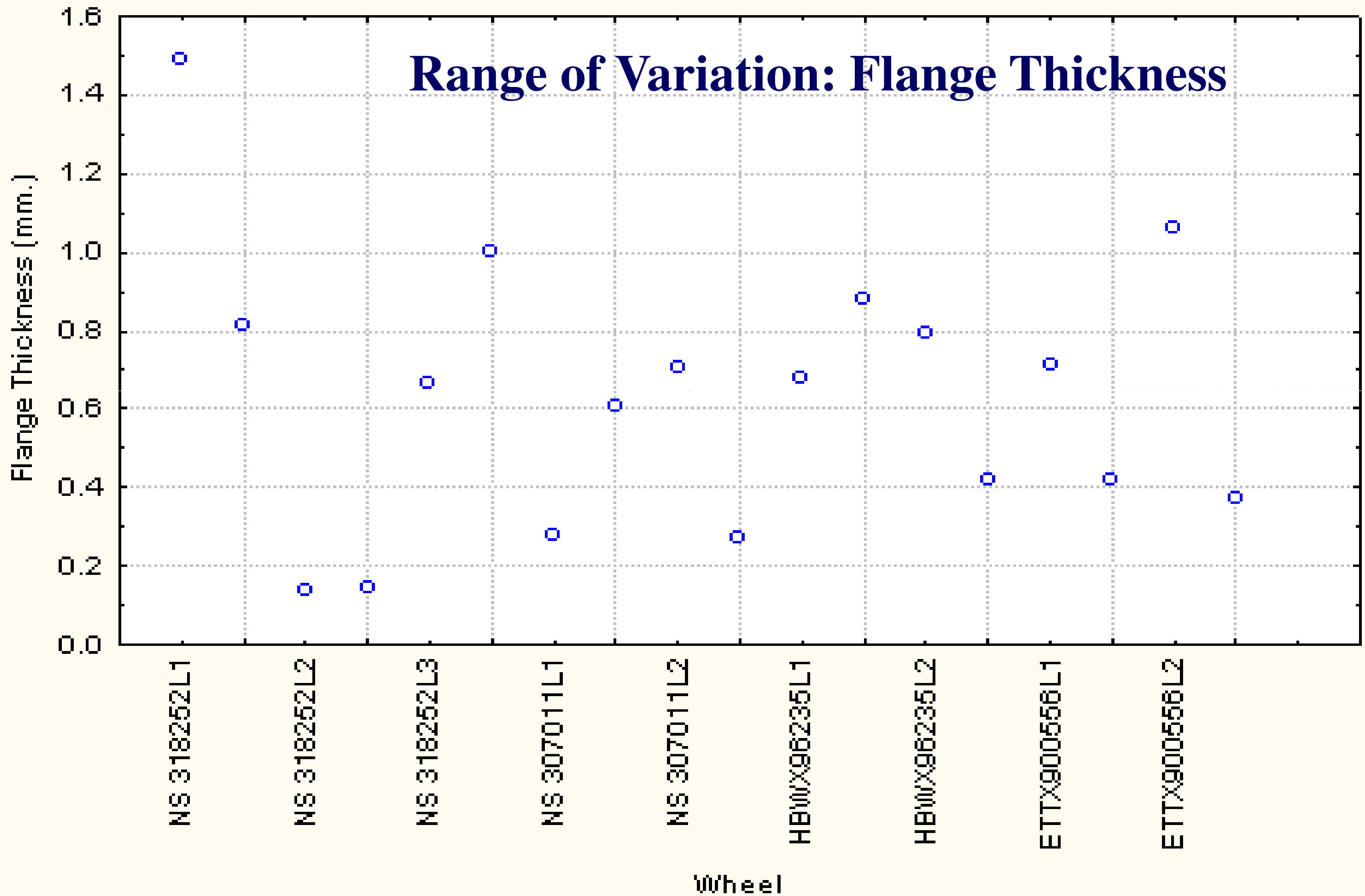
Flange Height – Steel Gage Equivalent



Tread Hollow



MiniProf Gage R&R Study - Loudon 2001 Data



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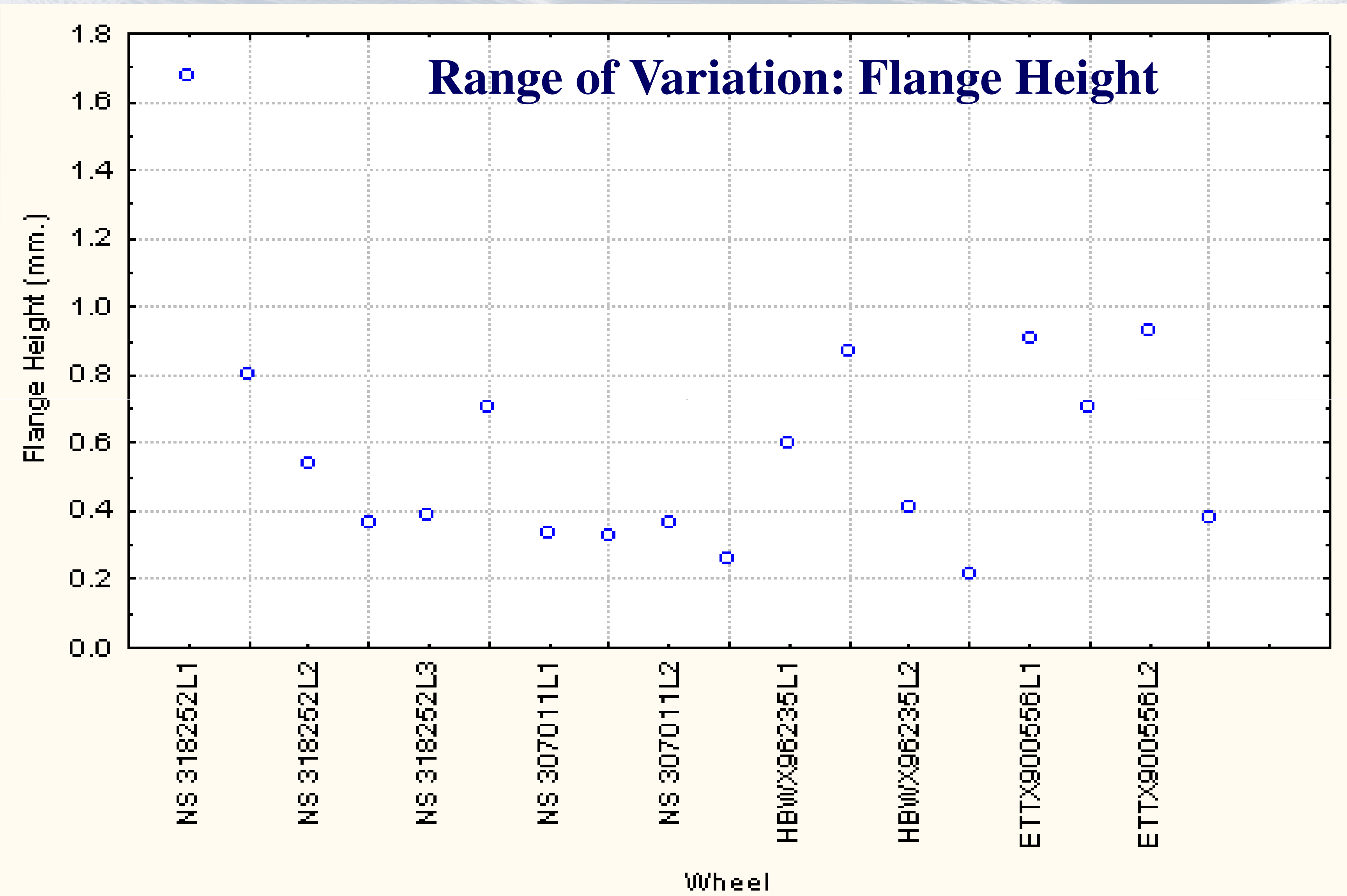
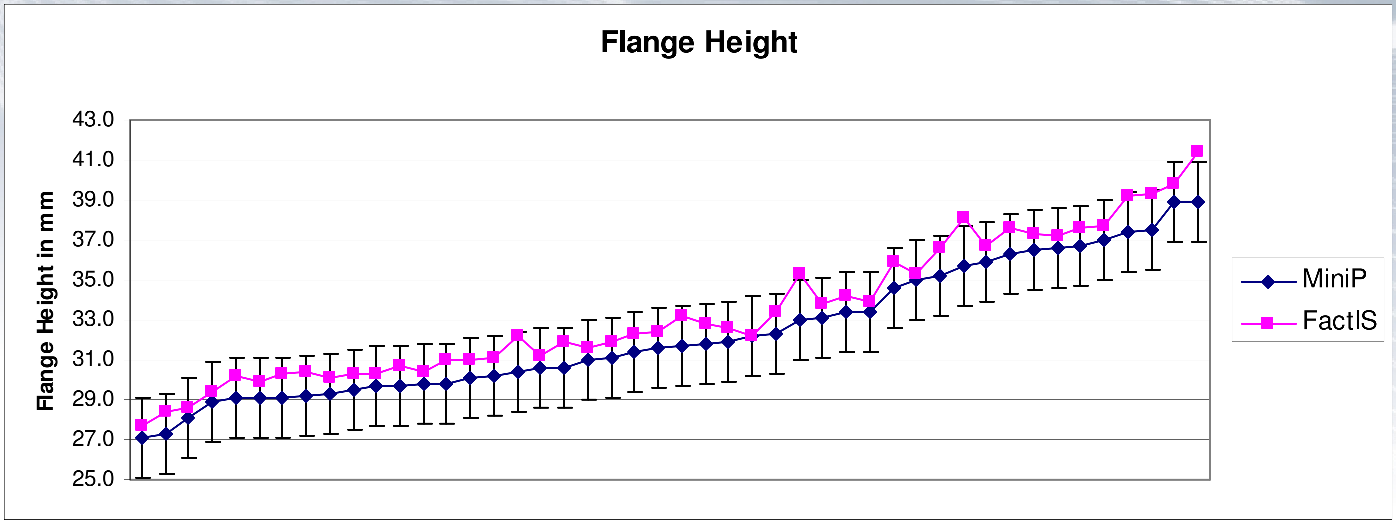
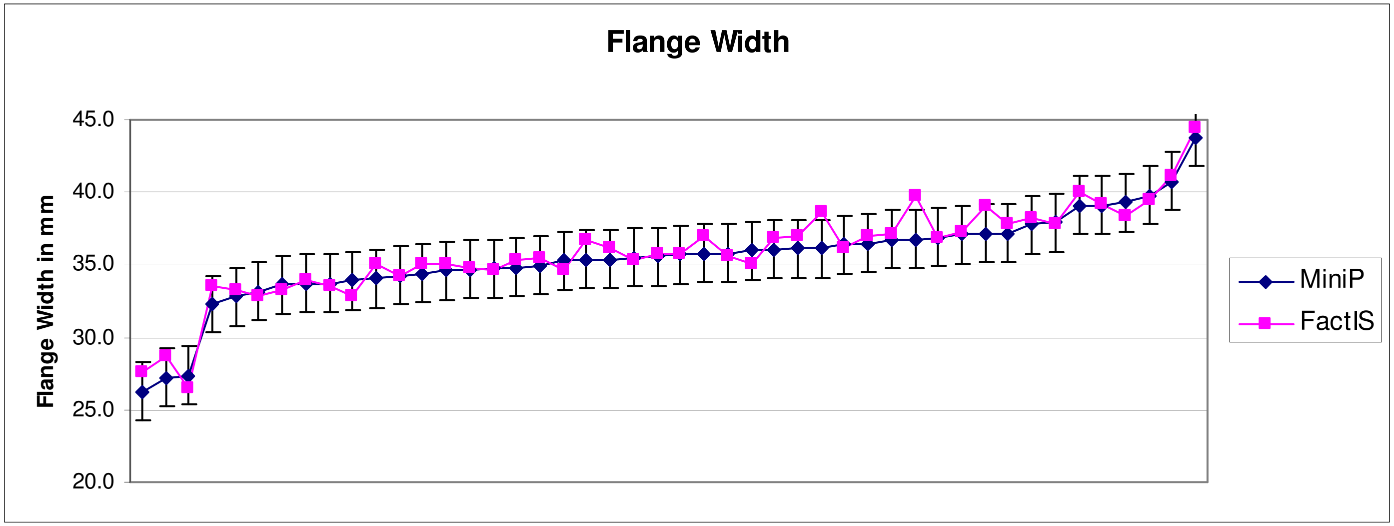


Field Audit Results





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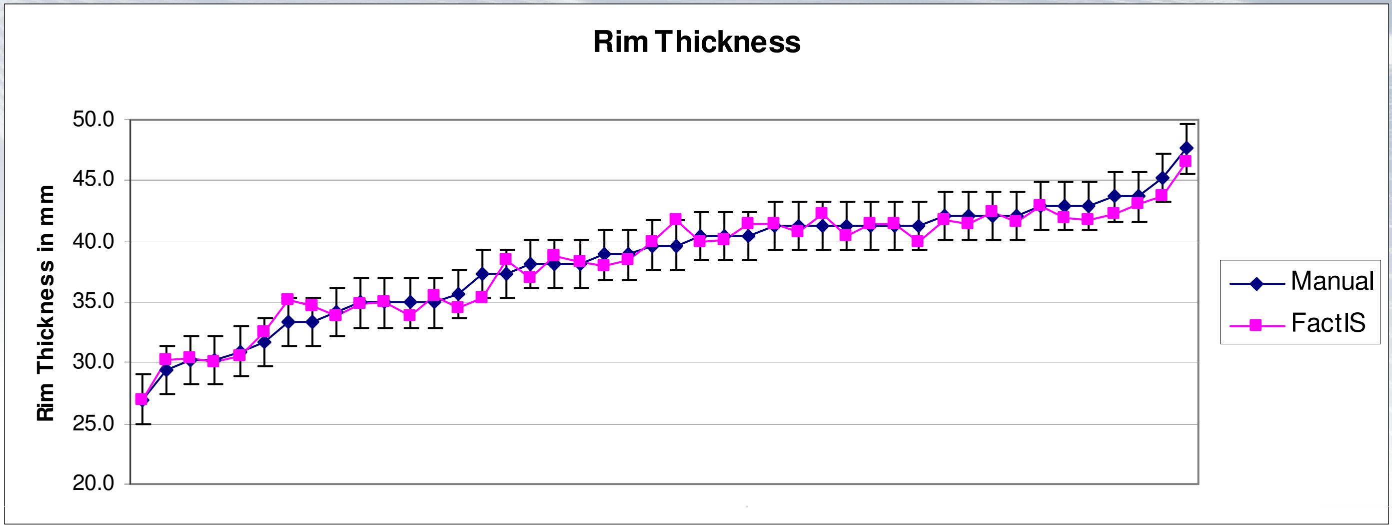

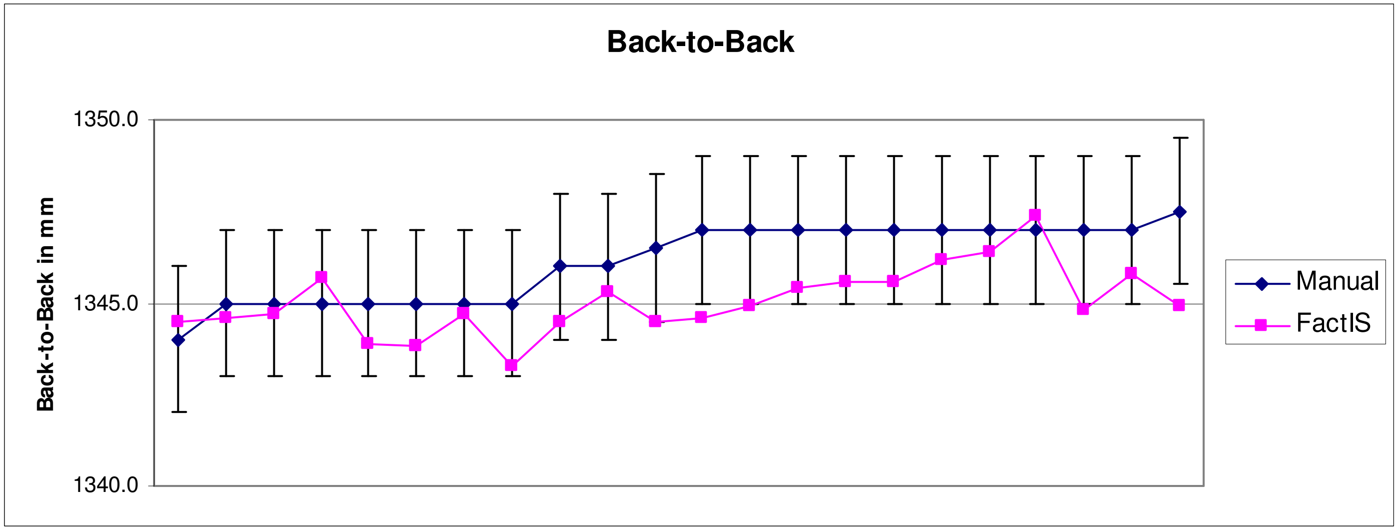

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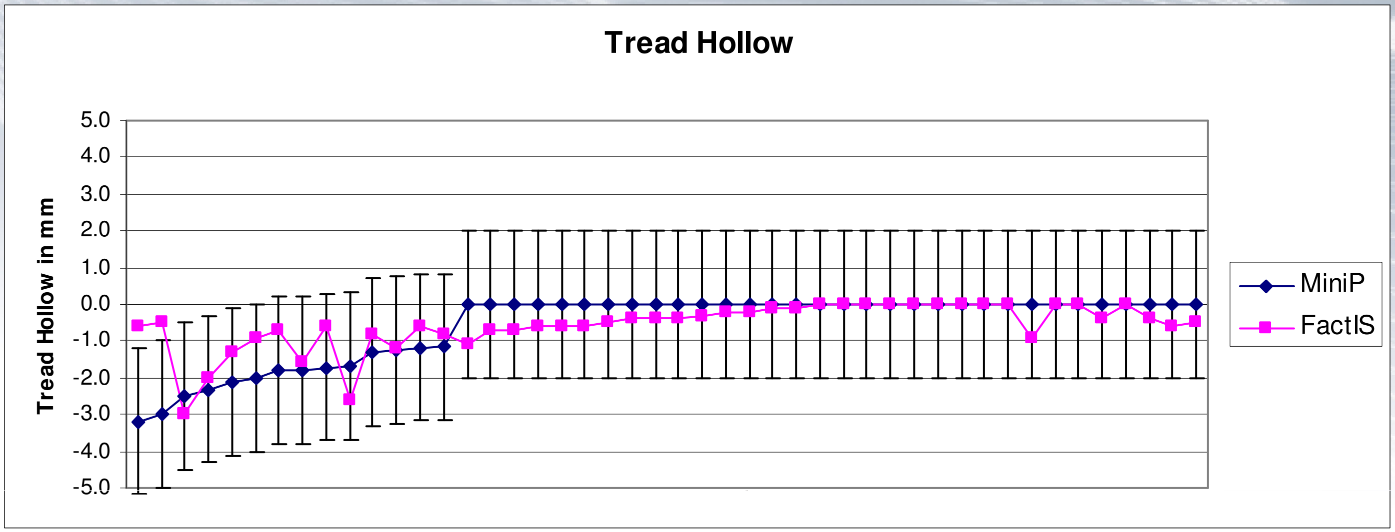


CFR Parts 215, 231, & 232: 1000 Mile Brake Inspection

1000-Mile Brake Inspection

- **Hot and cold wheels can be detected through thermal imaging.**
- **Can determine if brakes are inoperative when brakes are applied or stuck after brakes are released.**
- ***Performance-based* approach to satisfy requirement in CFR 49, 232.205(b) for brake function test at the 1000-mile inspection.**

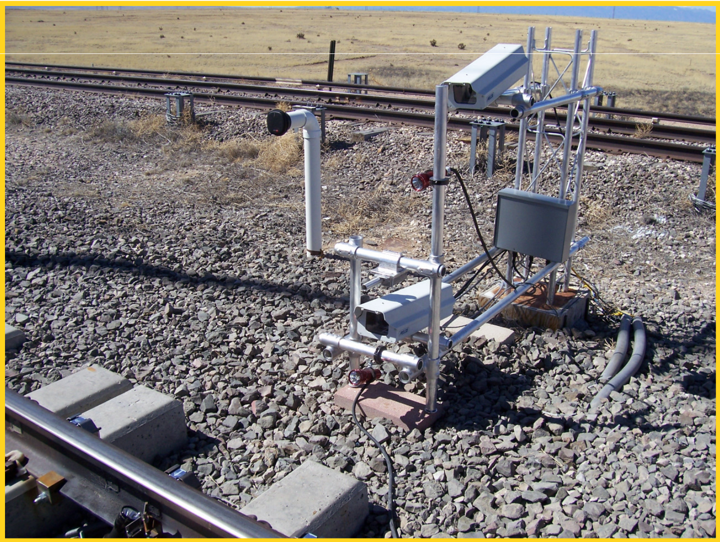
Wayside "Machine Vision" System

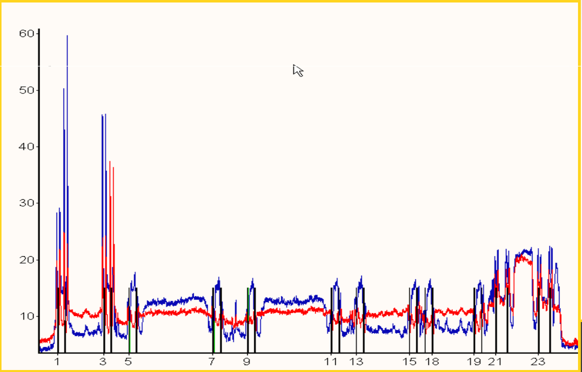
Brake Shoe Inspection

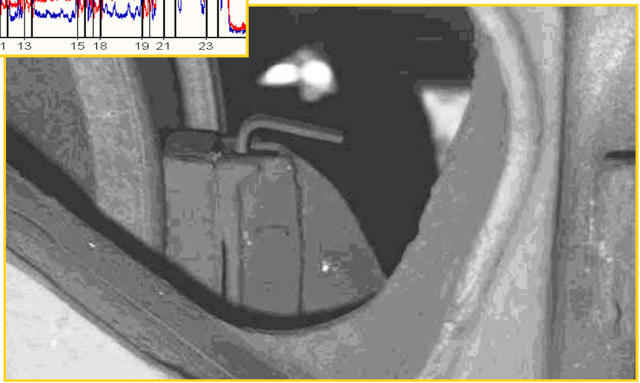
System Image

Class 1A Brake Test Demo

- **Multiple technologies**
  - Thermal sensors to detect heat generation at shoe/wheel interface
  - Machine vision to assess brake shoe condition





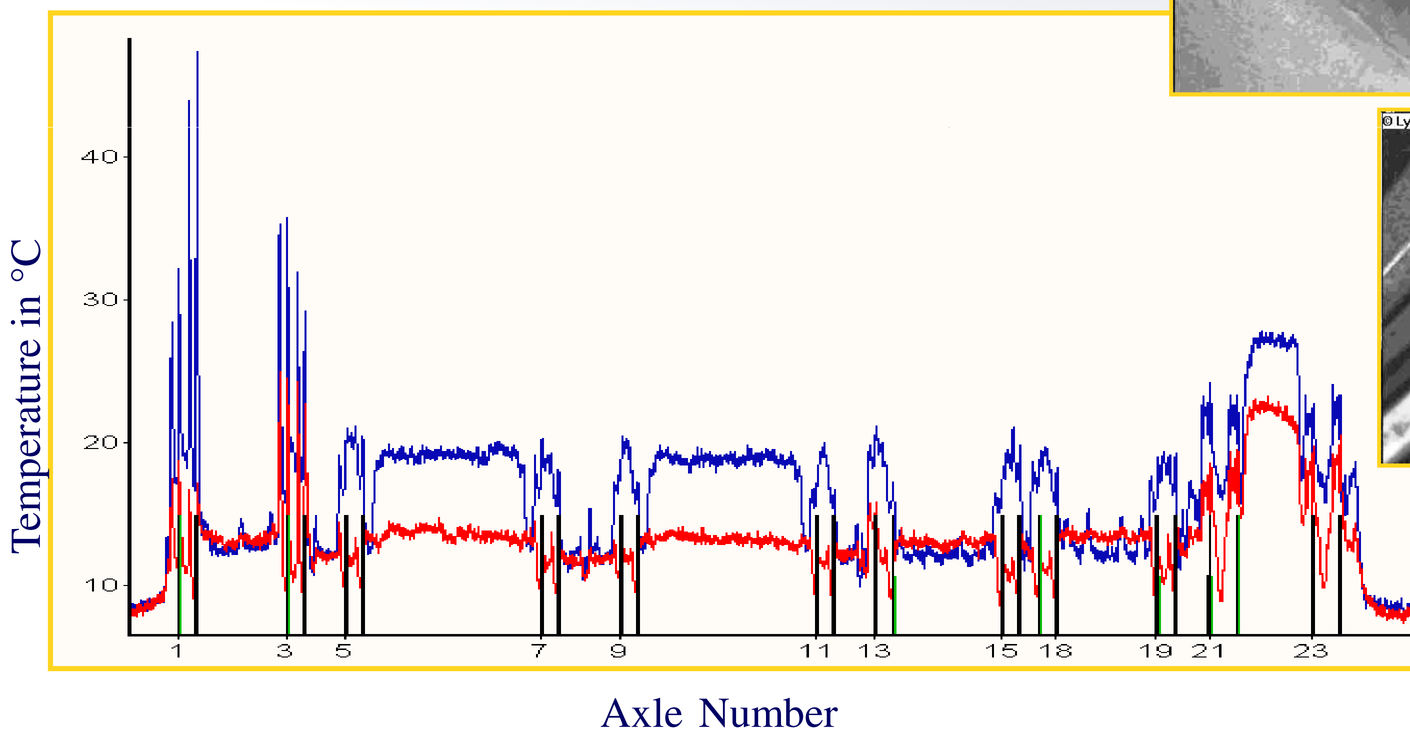


Class 1A Brake Test Demo

- **Proposed Test Sequence**
  - Safety First
  - 5 car train, 3 coal hoppers, 2 container flats, all loaded
  - Pass @ 15 mph, brakes released, 1 hand brake set
  - Pass @ 15 mph, 10# brake pipe reduction for 5000’, one car w/air brakes cut out
  - Show results between runs

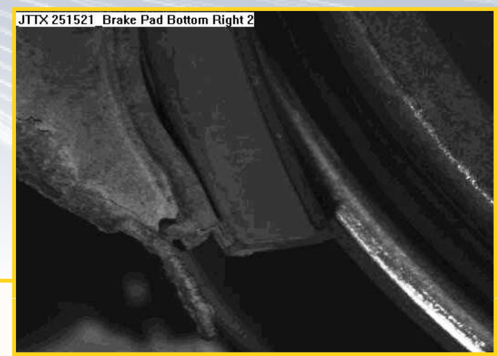
Class 1A Brake Test Demo
Sample Test Results

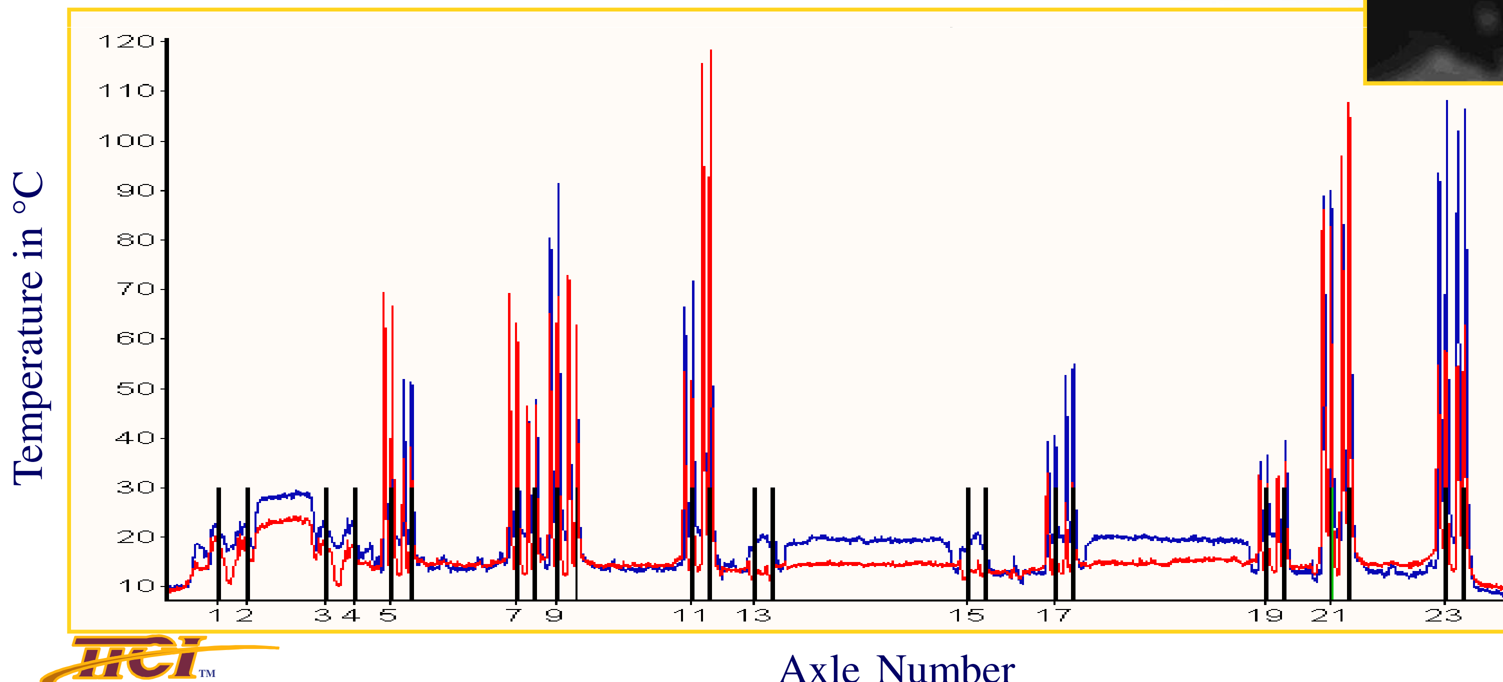
Hand brake applied on one car



Class 1A Brake Test Demo
Sample Test Results

Brakes applied on consist, one car w/inoperative brakes





CFR Parts 215, 231, & 232: Brake Systems

Other Brake Inspection Criteria

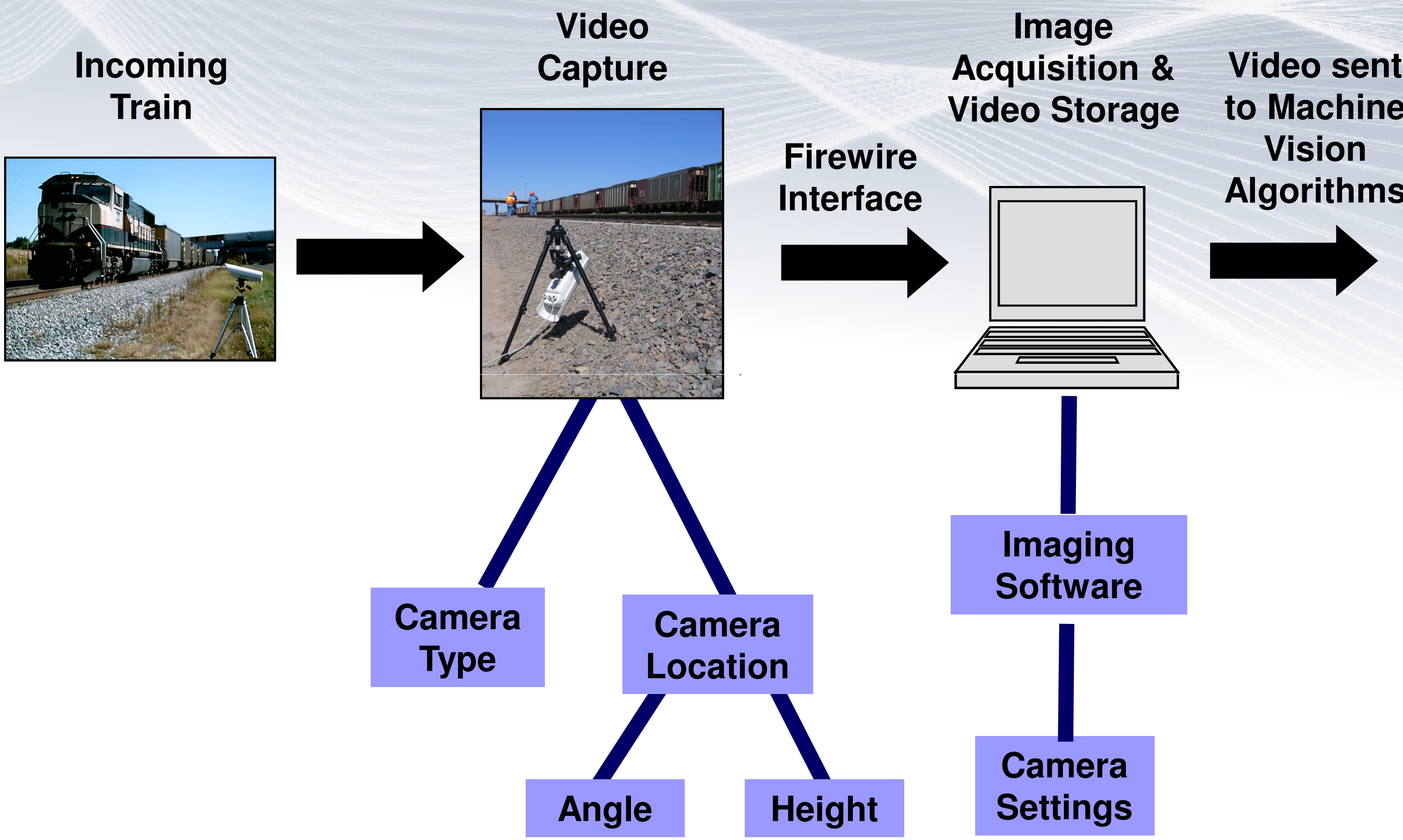
- In addition to a functional test, 49 CFR 232.207 requires brake rigging & all brake equipment 'be properly secured'.
- With more specific criteria, this inspection could be performed through machine vision.
- Alternatively, a successful functional test of the brake system implies that all brake components are in proper working order: *Performance Based Approach*

CFR Parts 215, 231, & 232 Review

Inspection Module Development

- Current technology can be further developed to satisfy some requirements.
- Additional modules:
  - Brake Condition Monitoring Module
  - Coupler/Draft Gear Module
  - Truck Component Module
- Other technologies:
  - Cracked Axle Detection
  - Cracked Wheel Detection
  - Safety Appliances: Car Features

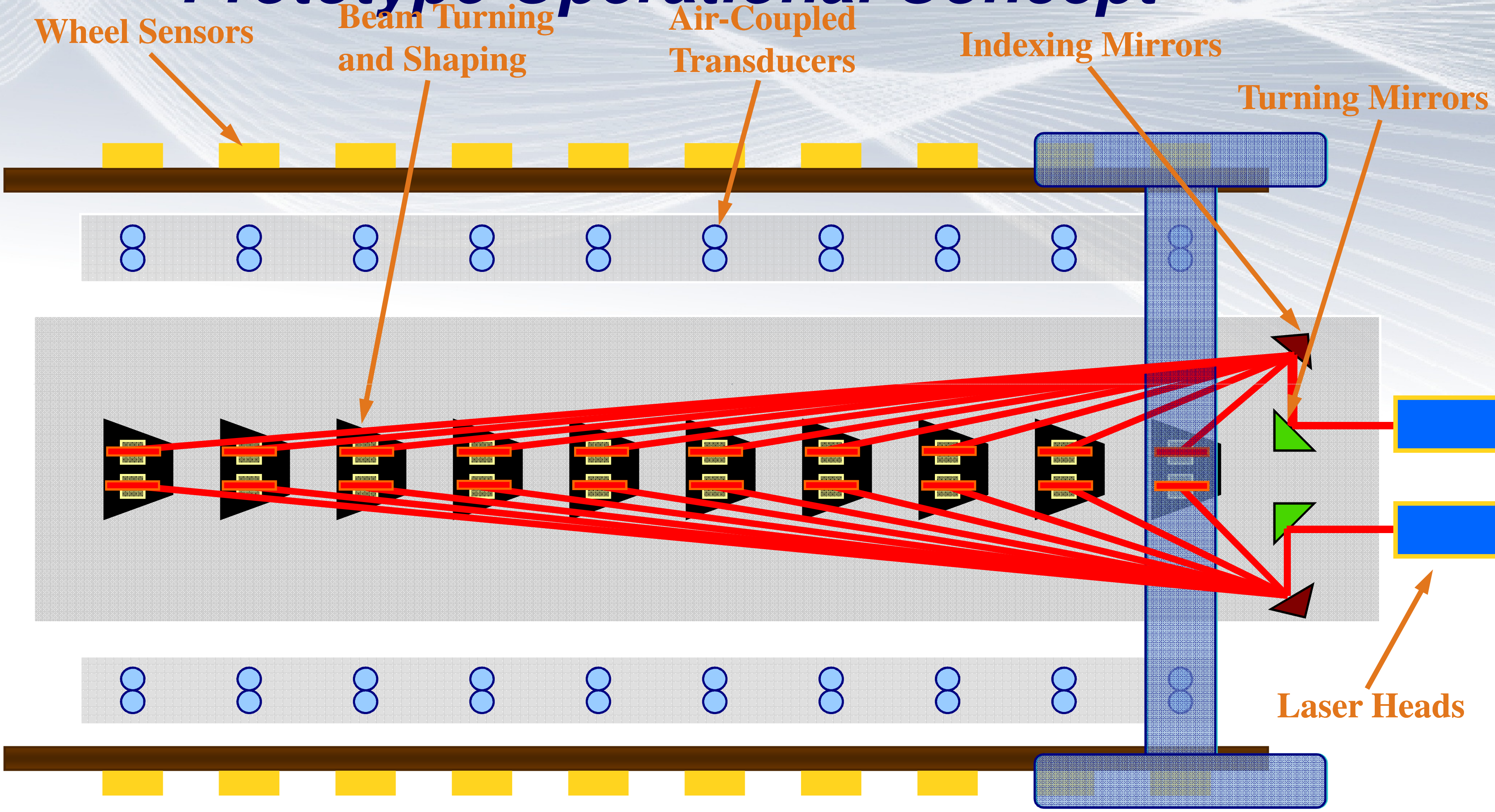
Safety Appliance Inspection: Image Acquisition System



Axle Crack Detection System Prototype Design

- **Several Designs Considered**
- **Design Criteria**
  - Low speed system (5-20mph)
  - Inspection every 3" around axle circumference
  - Focus on axle body with potential of expanding to wheel seat area
- **Design concept incorporated:**
  - Array of 40 stationary ultrasonic transducers
  - 10 sliding mirrors to direct lasers to axle
  - 2 lasers to accommodate 2 axles per truck
  - Array of lenses to focus laser on axle

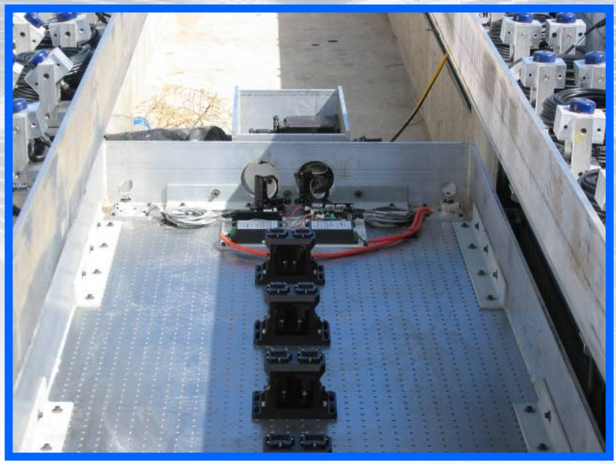
Axle Crack Detection System Prototype Operational Concept

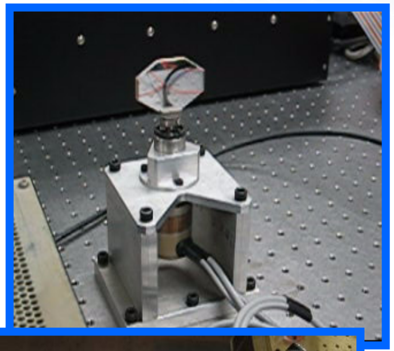


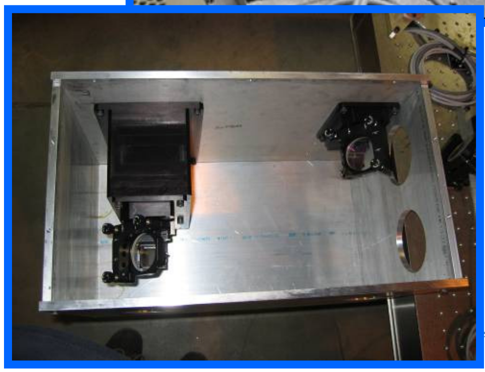
Play

Axle Crack Detection System
Prototype System Components





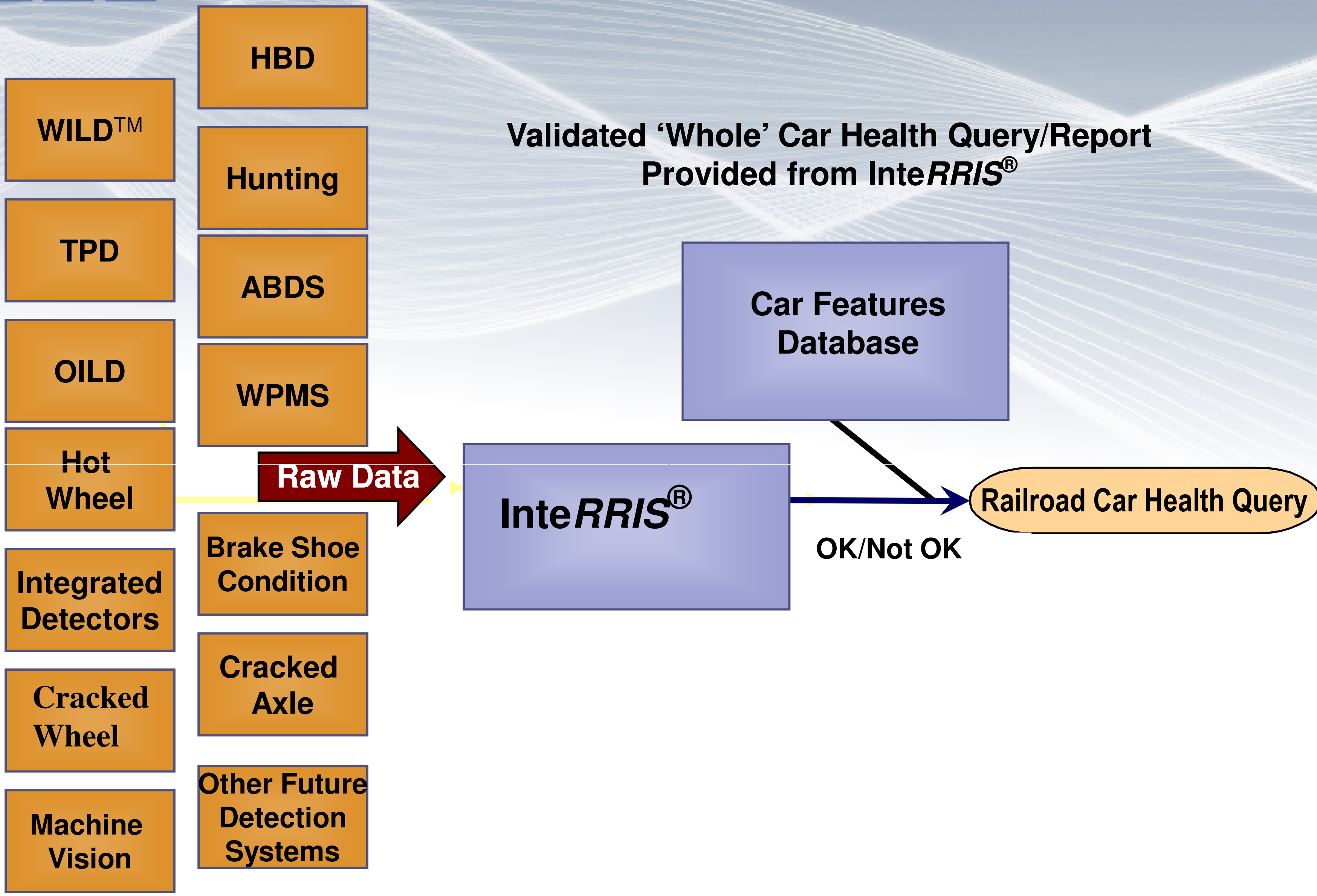




TDTI – The Future

- **Integrated network of wayside inspection stations**
  - **Quantitative data on components of individual vehicles**
  - **Data trending analyses → predictive maintenance strategies**
- **Systems with Multiple Sensor Technologies**
  - **Video Imaging + Thermal Senors for 1000 mile Brake Inspections**
  - **Video Imaging + Laser Ultrasonics for Cracked Axle & Wheel Detection**
- **Systems of Multiple Modules & Database Catalogs**
  - **Supplant manual in-bound and out-bound inspections**
  - **Condition and location of safety appliances**
  - **Inspection of vehicles for non-standard features, including contraband or explosive devices**

Technology-Driven Train Inspection




Questions?


Thank You!