William W. Hay Railroad Engineering Seminar

"An Overview of AAR Railway Research and Technology Innovation"

Semih Kalay

Senior Vice President, Technology

TTCI® Transportation Technology Center, Inc.

Date: Friday, October 14, 2016 Time: Seminar Begins 12:15

Location: Newmark Lab, Yeh Center, Room 2311
University of Illinois at Urbana-Champaign

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RAILTEC
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

Students welcome and encouraged to attend!

NURail Center

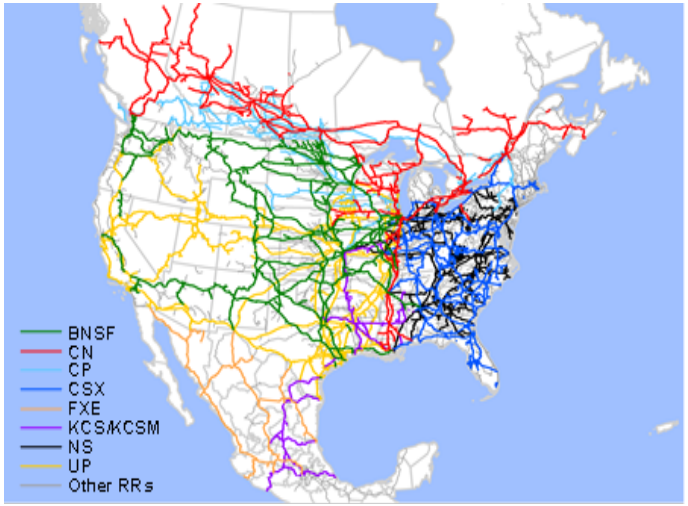
North American Research and Technology Innovation Program to Improve Safety and Efficiency

Semih Kalay
Senior Vice President, Technology

September 2016

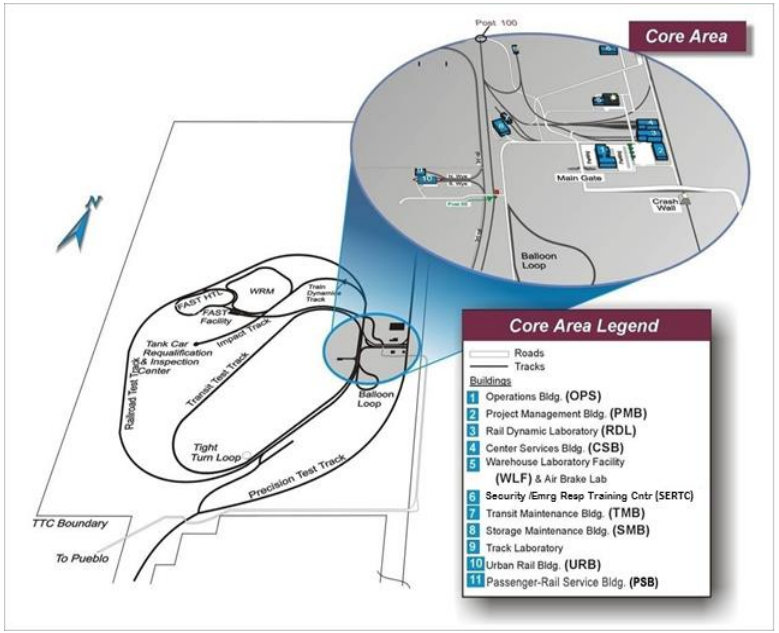
Railroad Facts and Figures

- $77.7 billion in Operating Revenue ($17 b Can, $2.8 b Mexico
- 94,300 miles of road owned (30k miles CN & CP, 7.5k Mexico)
- Major US freight RRs own 60,000 bridges
  - Over 1,400 miles or 7.6 million feet
  - Each major RR owns more than 10,000 bridges
- Over 26,000 locomotives
- Over 1.56 million freight cars
- Average length of haul:1006 m
- 1.85 trillion revenue ton miles
- Almost 72 cars per freight train
- 479 RTM/gal of fuel



Source: Railroad Facts – 2014 Edition, AAR

TTCI – Transportation Technology Center, Inc.



- Wholly owned subsidiary of the Association of American Railroads
- Located in Pueblo, Colorado
- Operates the Transportation Technology Center on behalf of the Federal Railroad Administration
- Focus on research, development, testing and training for the rail industry
- 270 Employees
- 52 square mile facility with 48 miles of track
- Full-size laboratories capable of testing rail cars

TTCI® Transportation Technology Center, Inc.

2016 North American Strategic Research Initiatives Program

North American Technology Developments
AAR Strategic Research Initiatives Program

- **Strategic Research Initiatives Program (SRI) addresses current and future strategic issues relating to the North American rail industry**
- **Research Objectives**

Improve Safety

- Reduce track and equipment-related derailments through technology development

Improve Reliability

- Reduce or eliminate line-of-road failures

Improve Efficiency

- Increase productivity and reduce costs

2016 AAR Strategic Research Program

- **Wheel/rail interface management**
  - Wheel/rail interface maintenance
  - Root causes of rolling contact fatigue
- **Improved car performance**
  - Integrated freight car truck
  - Dynamic load environment
- **Vehicle/track performance**
  - Effects of short cars on bridges/track
  - Effects of Impact loads on rail failure
  - Loaded tank car/track interaction
- **Heavy axle load implementation**
  - FAST/HAL Operations
  - HAL revenue service monitoring
  - HAL revenue service-Northern megasite
  - Track structure for HAL coal lines
- **Improved braking systems**
  - Improved brake system performance
- **Train condition monitoring**
  - Technology driven train inspection
  - Automated cracked wheel detection
- **Track integrity monitoring**
  - Phased array rail flaw inspection
- **Improved car components and materials**
  - Strategies to prevent wheel failure
  - Optimized HBD performance
- **Special trackwork**
  - Improved special trackwork designs and materials
- **Bridge research**
  - Bridge life extension
- **Improved track components**
  - Improved rail welding
  - Improved rail performance
- **Improved performance track**
  - Investigation of rail wear Limits
  - Improved tie/fastener system performance
- **New technology implementation**
  - Equipment health monitoring technology
  - Equipment and track technology implementation

AAR Strategic Research Initiatives Program

Improved Safety

- **Reduce Track and Equipment-related Derailments Using Technology**

Track Integrity Monitoring

- Phased Array Rail Inspection
- Measurement of Rail Longitudinal Forces
- Onboard Bridge Inspection

Train Condition Monitoring

- Cracked Wheel Detection
- Technology Driven Train Inspection
- Improved Hot Box Detectors

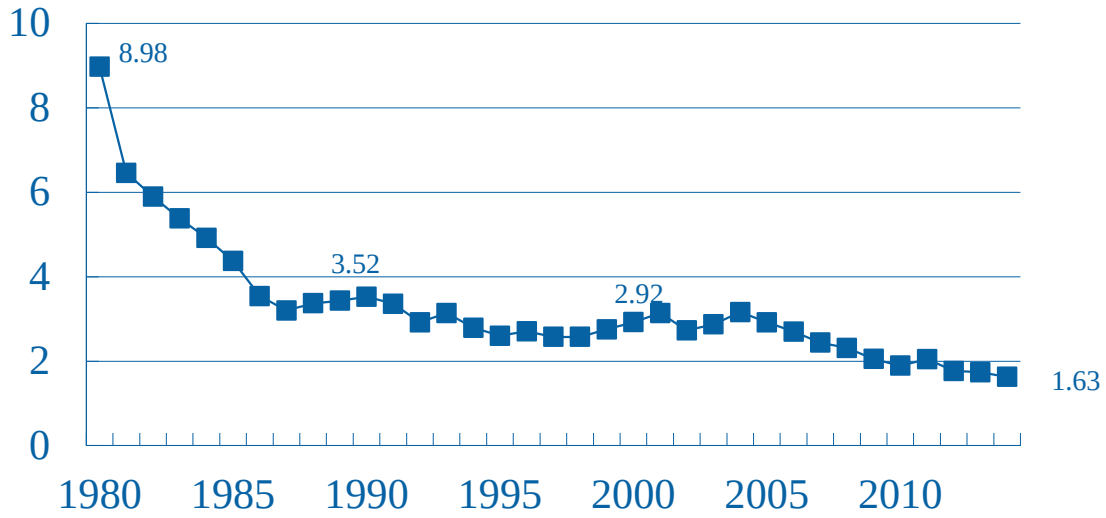
Improved Car Components

- Integrated Freight Car Truck
- High Performance Car Couplings
- High Performance Wheel Steels

Improved Track Components

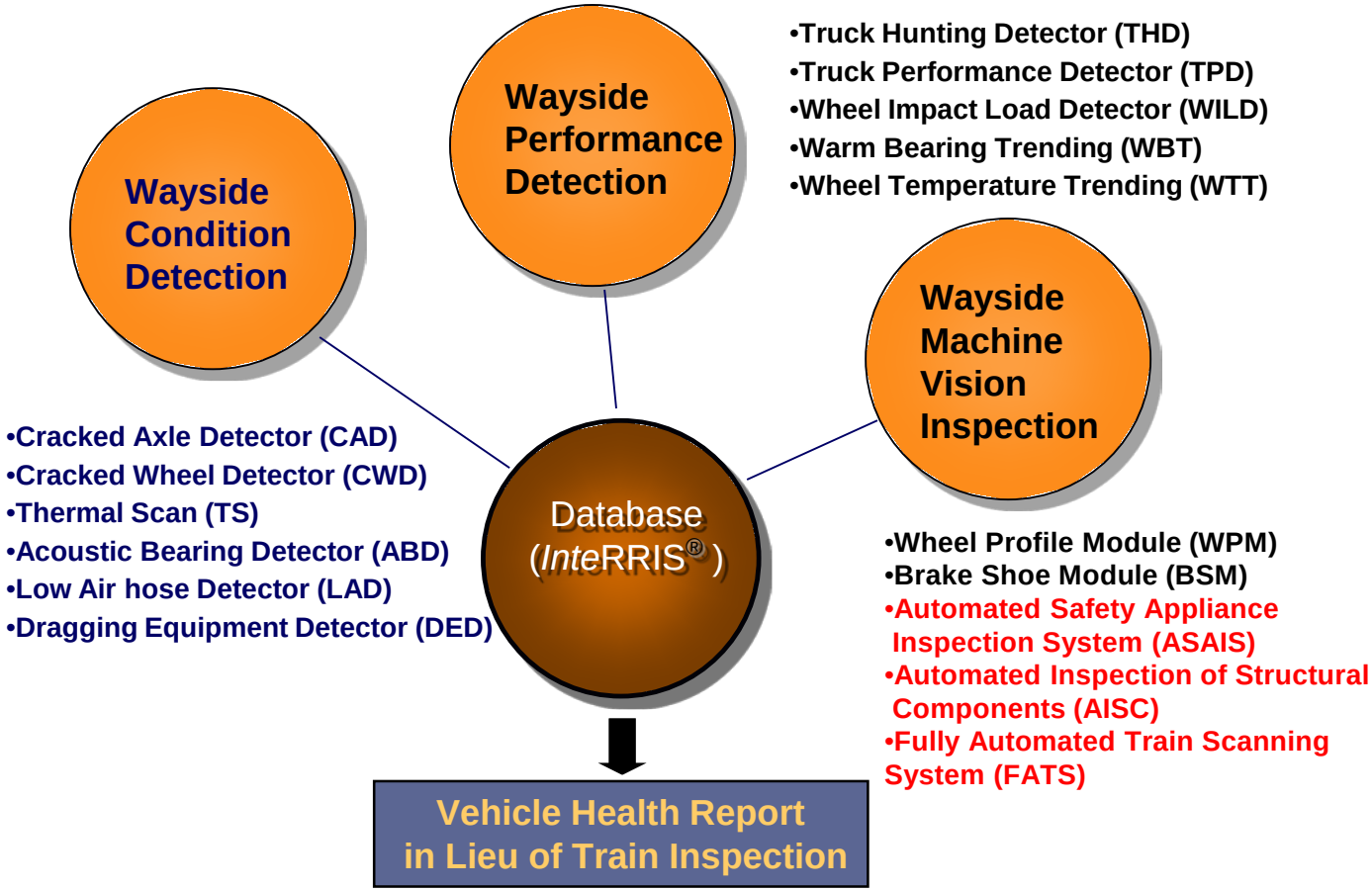
- Full-scale Evaluation of Track Components
- Implementation of Flange Bearing Diamonds
- Improved Rail Steels, Crossties & Welding

Derailments per Million Train-miles have Dropped to a New Low: 82 percent since 1980, and 44 percent since 2000

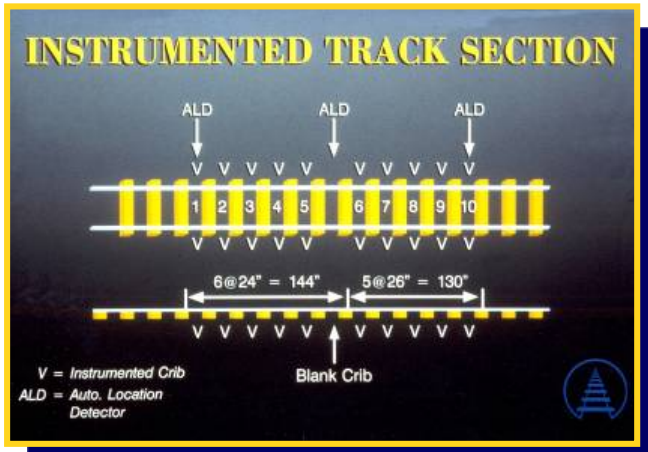


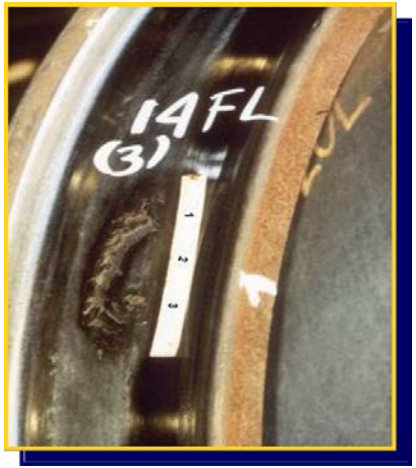
Sources: http://safetydata.fra.dot.gov/officeofsafety/publicsite/summary.aspx (2014 data).
FRA, Railroad Safety Statistics Annual Report, 1997-2010, Tables 1-1, 5-6.
FRA, Accident/Incident Bulletin, 1980-1996, Tables 19, 36.
Note: Excludes grade crossing accidents. Data is for 2014.

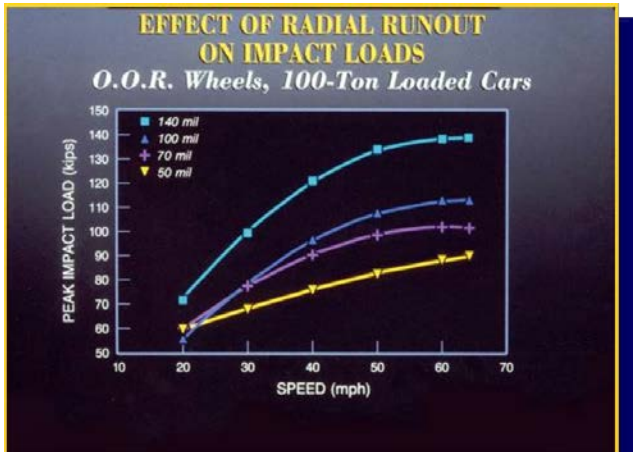
North American
Technology Driven Train Inspection



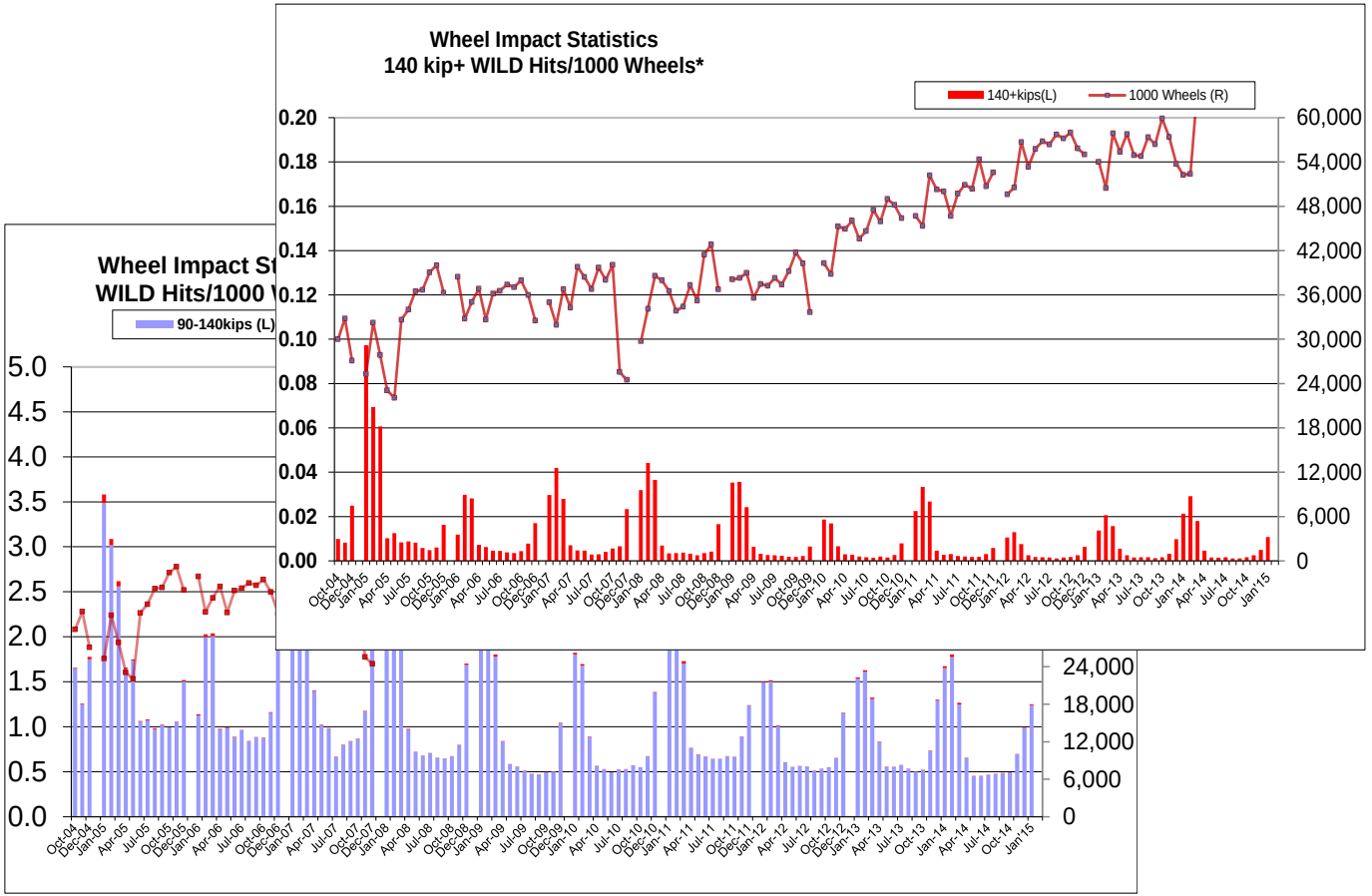
Impact Load Detectors





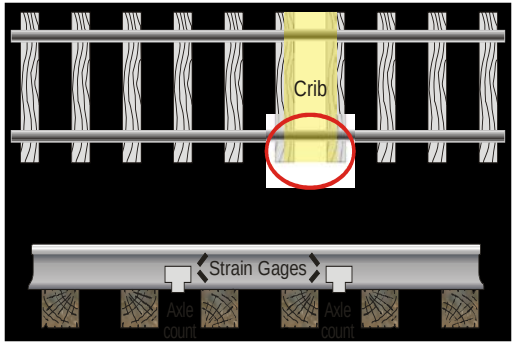


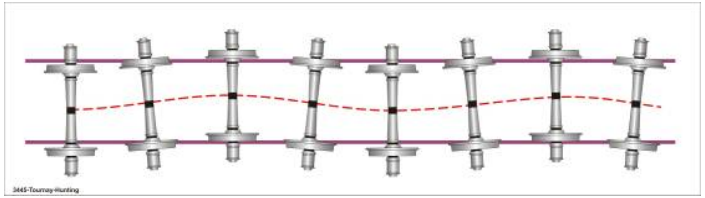
Rate of Wheel Impact Readings in North America



Hunting Detector

- **Instrumented cribs measure vertical & lateral wheel loads**
  - to establish a hunting index (HI) over a length of track

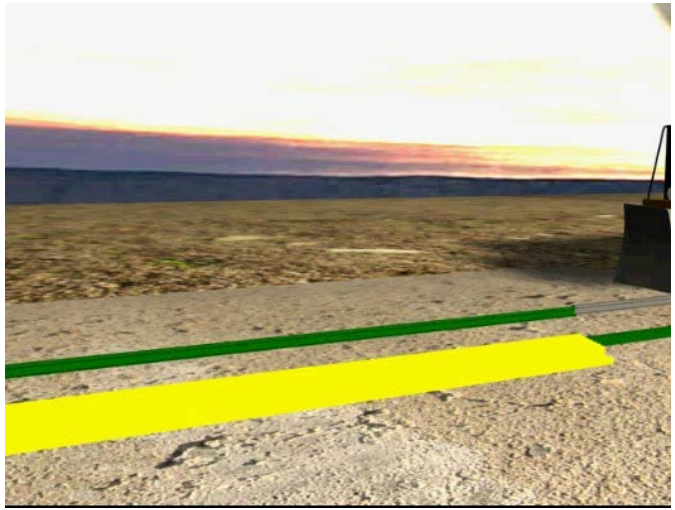




- THD alerts in the AAR Field Manual — Rule 46.A.1.e
  - A single LBFoster, Salient Systems, detector absolute value at least 0.50
- Tbogie optical detector system
  - Tracking indices

Cracked Wheel Detection

- **Goals:**
  - Develop a wayside inspection system
  - Reduce derailments resulting from broken wheels



Maximize Safety by Significantly Reducing Wheel-Caused Derailments

Automated Cracked Wheel Inspection Systems

Solutions: Facilitate development, testing, and evaluation of new and alternative cracked wheel detectors capable of inspecting all trains

Vehicle Health Monitoring Systems: Next Generation Cracked Wheel Detection Systems

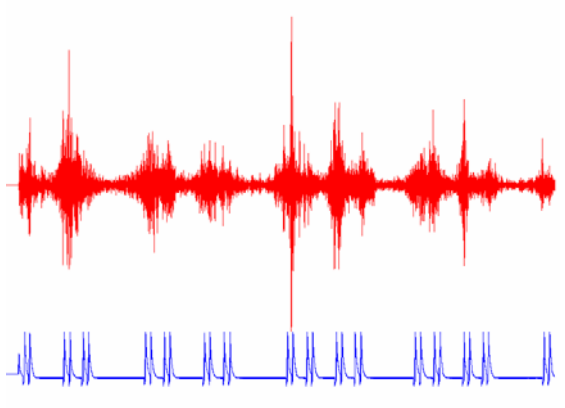
- **Cost-effective, Less Complex Systems Needed**
- **TTCI Research Underway to Accelerate Development & Implementation of New Systems**

Tycho ACWDS

Trackside Acoustic Bearing Detectors in North America

BNSF - Arkansas

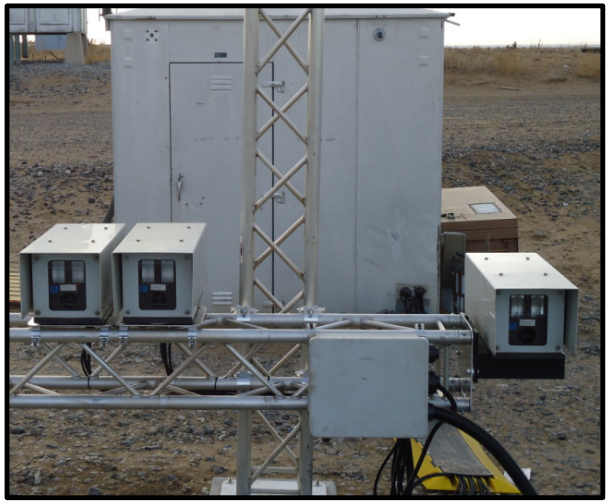
Deep cone spalling



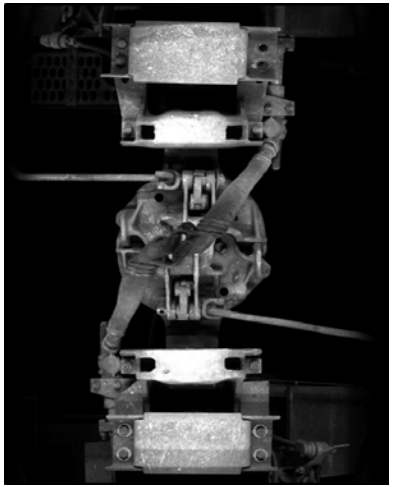
Maximize Safety and Efficiency by Automating Equipment Inspections

Challenges

Reliable Detection Systems



Institutional and Regulatory Barriers to Implementations



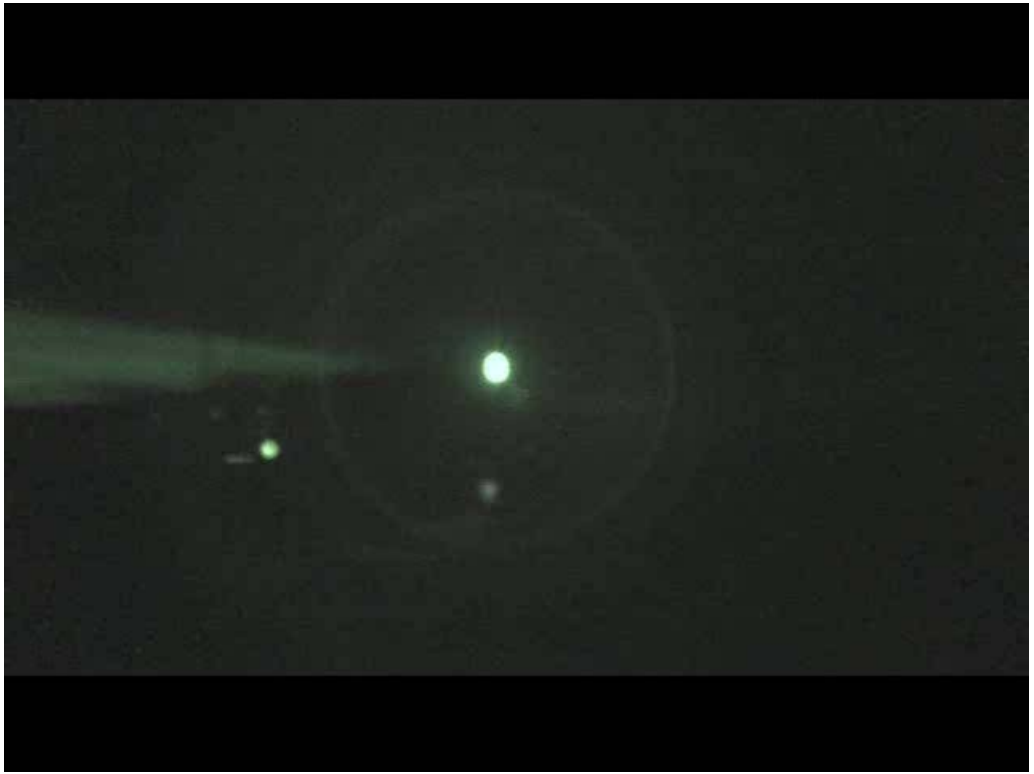
End Products: New and alternative machine vision detection systems capable of inspecting all trains at all times under all weather conditions

Technology Driven Train Inspection
Fully Automated Train Scanning System

Fully Automated Train Scanning System:

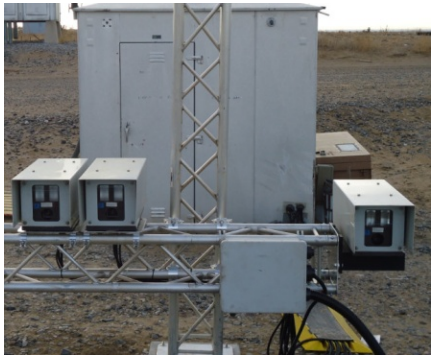
- **Ongoing applications include:**
  - **Car underbody**
    - Truck component details
    - Coupler securement/draft pocket inspection
    - Brake rigging details
  - **Top and side views**
    - Shifted / imbalanced loads
    - Unsecured lading
    - Top chord condition
  - **Security applications**
    - Tank car inspection
    - Foreign object detection

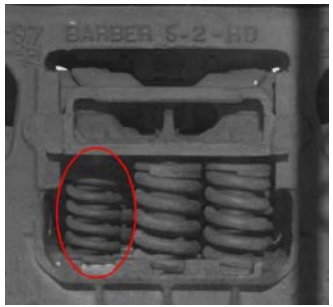
Technology Driven Train Inspection
FATSS

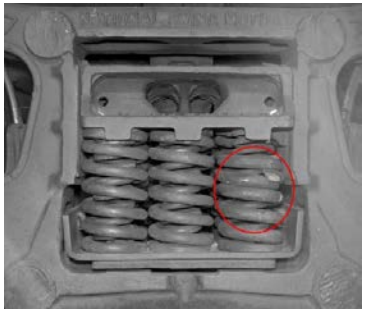
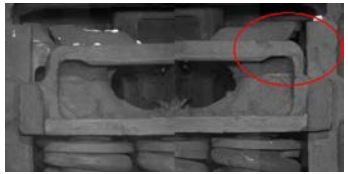
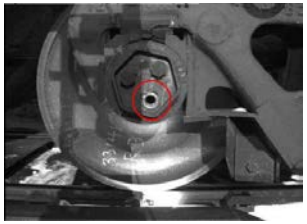


♦Machine-vision Inspection of Truck Details

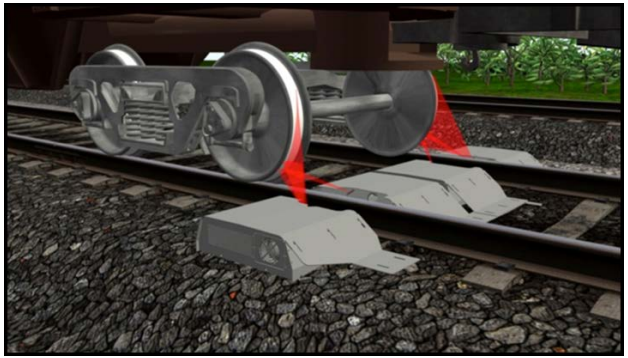
- Three vendors chosen to demonstrate truck detail inspection modules at FAST



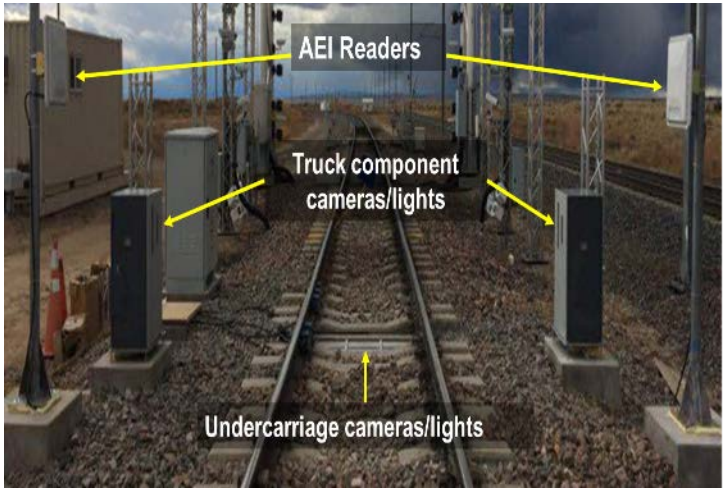
Wheel Profile Measurement



What is Next for Machine Vision Car Inspection Systems?

Locomotive Underframe Inspection Systems

3D Machine Vision Systems

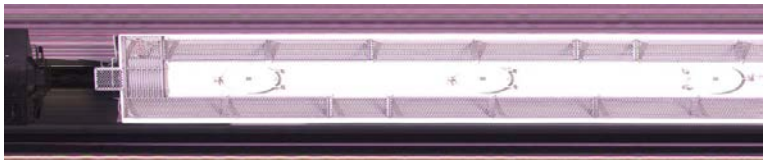


End Products: New and alternative machine vision detection systems capable of inspecting all trains at all times under all weather conditions

Duos VUE™ Train Imaging Portal

♦ Train Inspection Portal

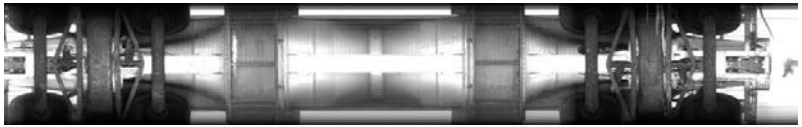
Top

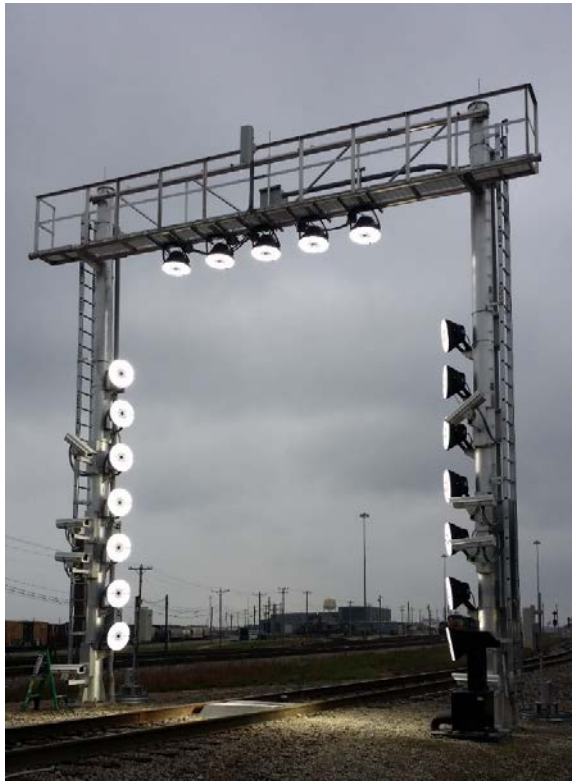


Side

Axle

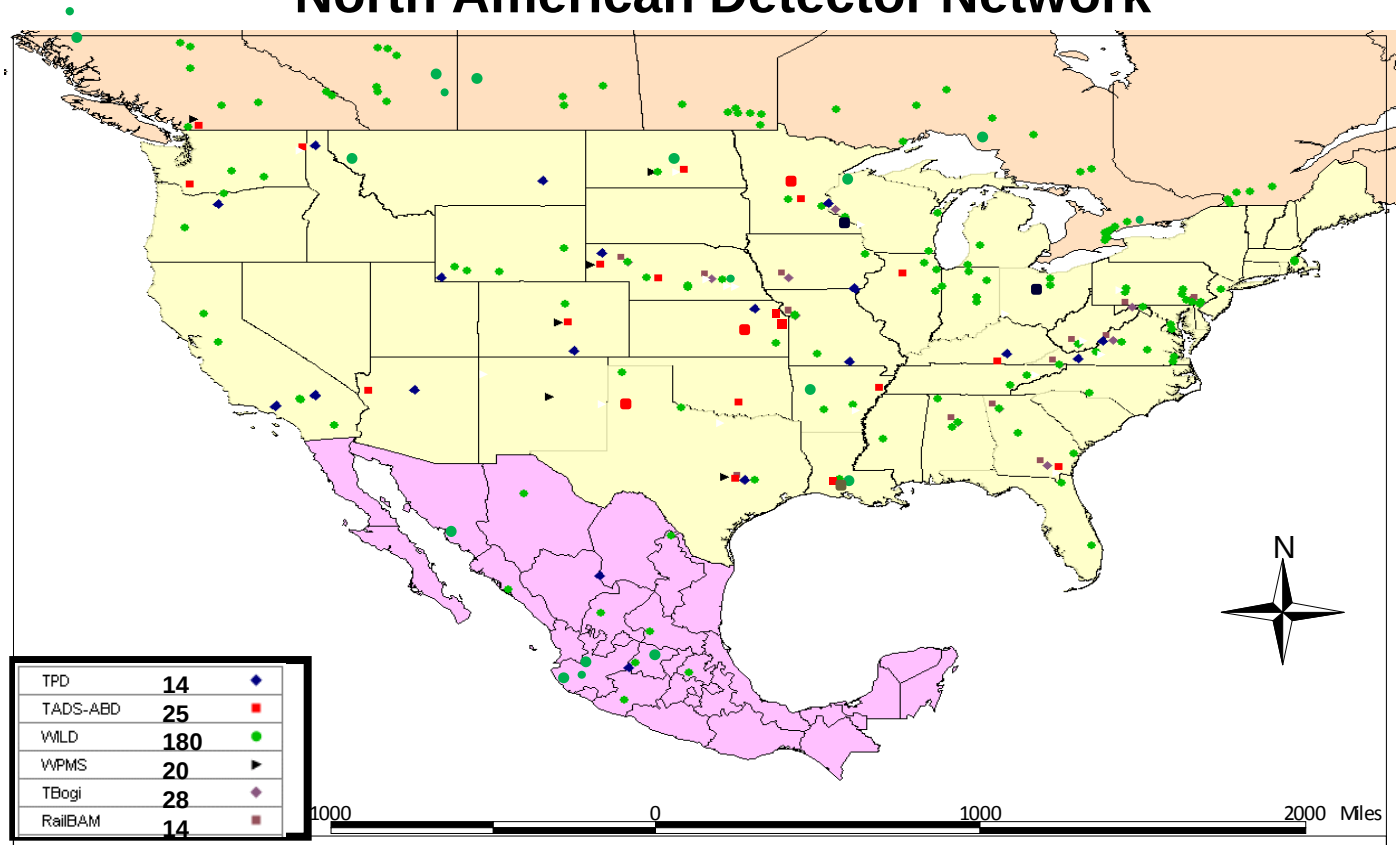
Bottom





RRs have spent millions to improve safety and efficiency.

North American Detector Network

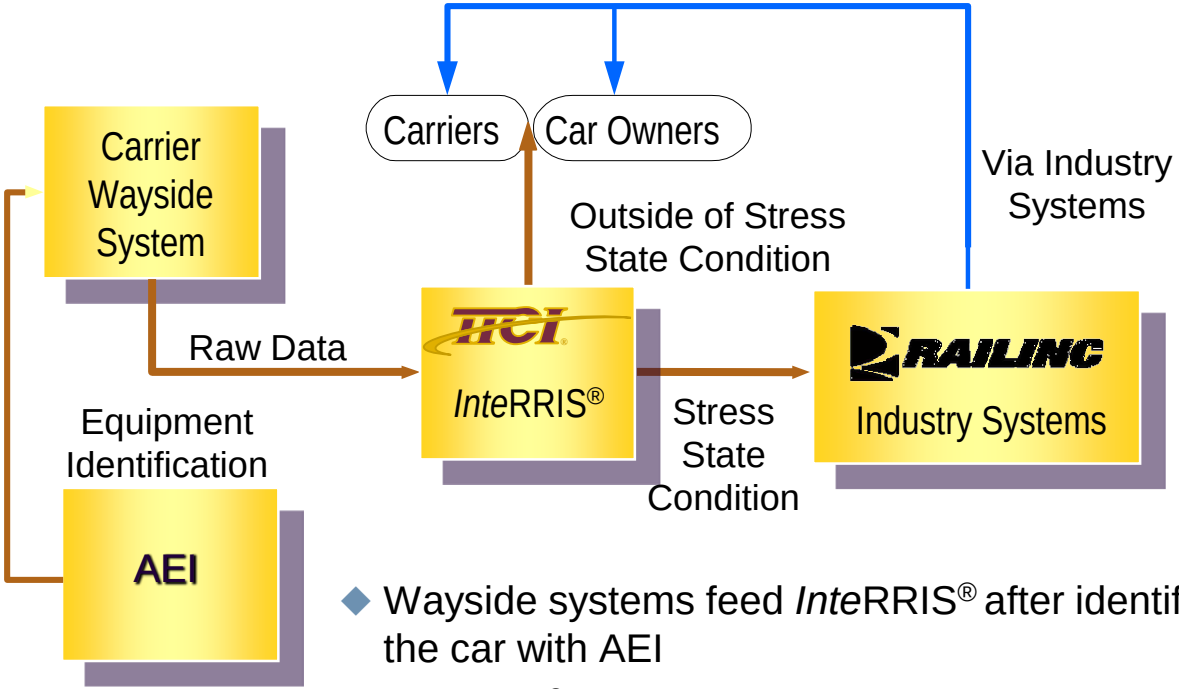


Wayside Detector Distribution

03/14/2015

Based on USGS DLG. 1:25,500,000, Geographic Projection, DD.
2015 (c) , Transportation Technology Center, Inc.

Implementation of Automated Equipment Health Monitoring & Management



- Wayside systems feed *Inte*RRIS® after identifying the car with AEI
- *Inte*RRIS® identifies a “Stress-State” condition
- *Inte*RRIS® communicates with Railinc Systems for processing

Industry Central Detector Database (*Inte*RRIS®): 2+ Terabytes of data stored (since 2000)

Incoming

- 300+ wayside detectors reporting
- ≈ 4,300 trains/day
- ≈ 400,000 vehicles/day
- ≈ 470,000,000 records/month

Outgoing

- 50+ outbound datafeeds
- 1.7 million vehicles monitored
- 1600+ daily event notification messages

Incoming From

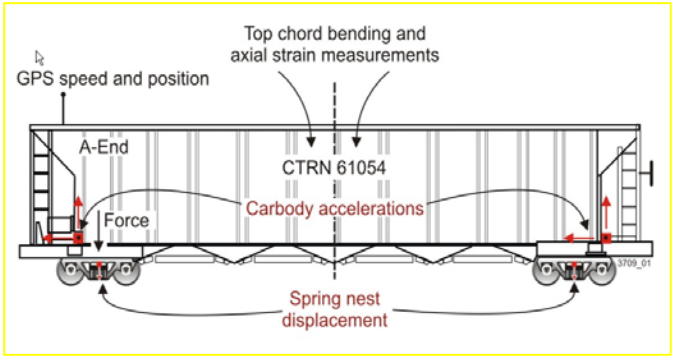
- WILD (wheel impacts)
- THD (bogie hunting)
- TPD (bogie steering)
- ABD (acoustic bearing)
- WPMS (wheel profile)
- OGD (bogie geometry)

Outgoing To

- Carriers
- Private Car Owners
- Shops\Fleet Managers
- 3rd Party Services
- Manufacturers
- Industry System (EHMS)

Technologies for Track and Vehicle/Track Interaction Inspection

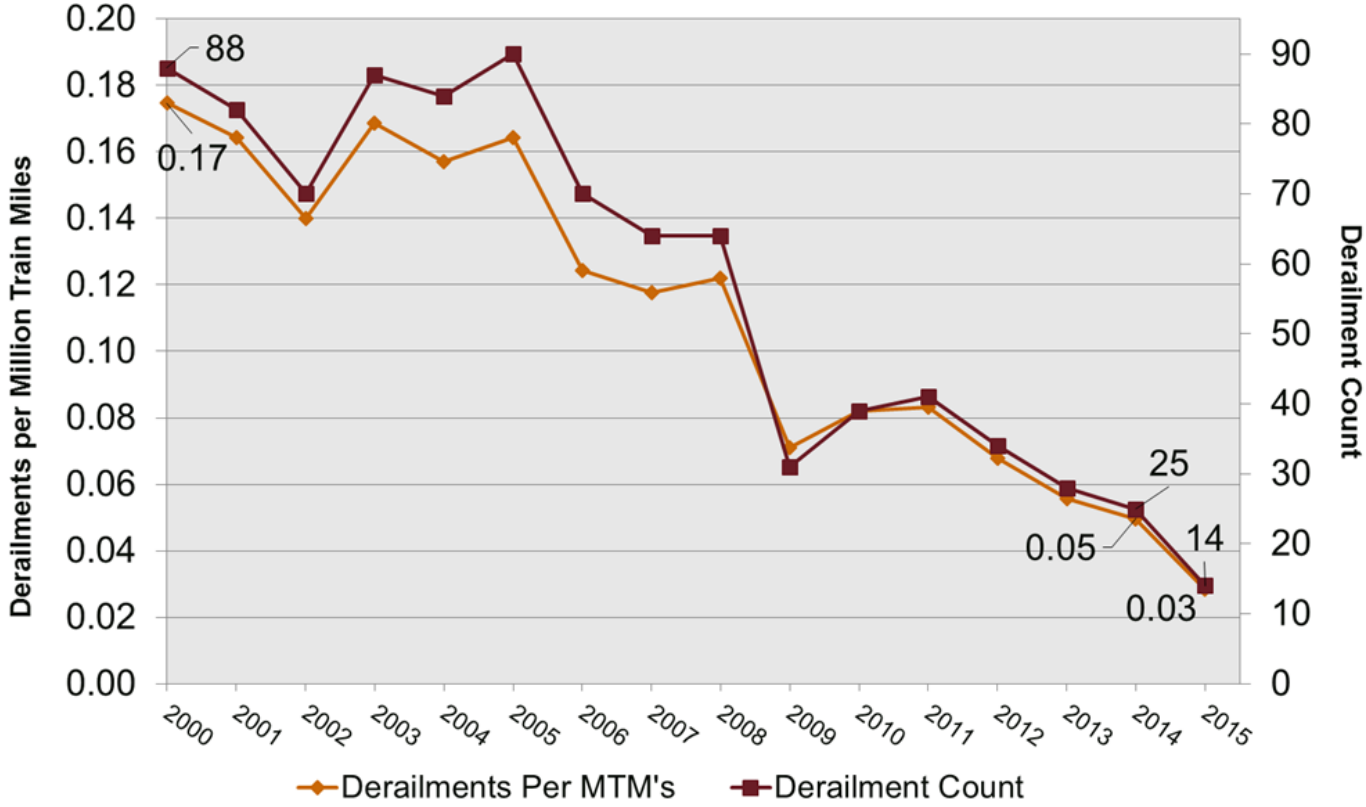
- **Vehicle mounted inspection systems**
  - Track Geometry Cars
  - Advanced Rail Flaw Inspection
  - Vehicle/Track Interaction (VTI) systems
  - Instrumented freight cars (IFCT)
  - Performance-based track inspection systems
  - Rail restraint measurement systems
  - Machine vision track inspection



Track Geometry Cars (TGC)

- **TGCs measure and report on exceptions:**
  - Track gage
  - Curvature
  - Cross-level
  - Alignment and Surface
- **Additional systems commonly found on TGCs include:**
  - Rail Profile and Corrugation Systems
  - Machine Vision Systems

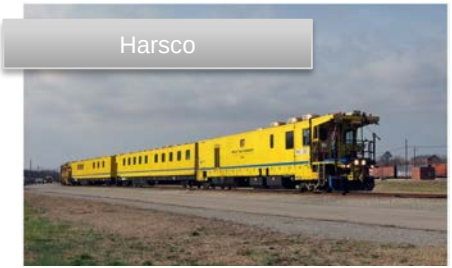
Broken Rail Train Derailment Rates involving U.S. Class I Railroads on Main Track have continued to drop



Rail Defect Detection

- **Rail is tested to identify internal defects by using an Ultrasonic Rail Flaw Testing Vehicle**

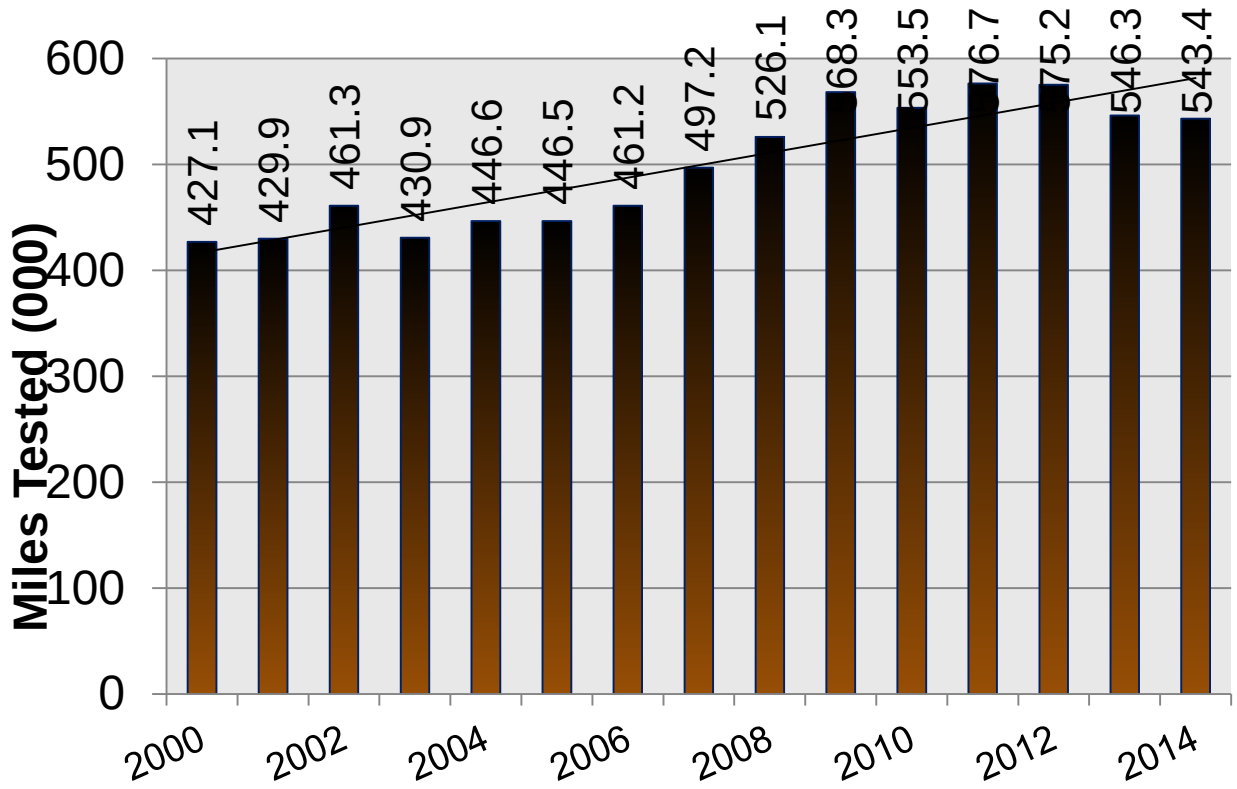
Harsco



Nordco Rail Services

Sperry Rail Service

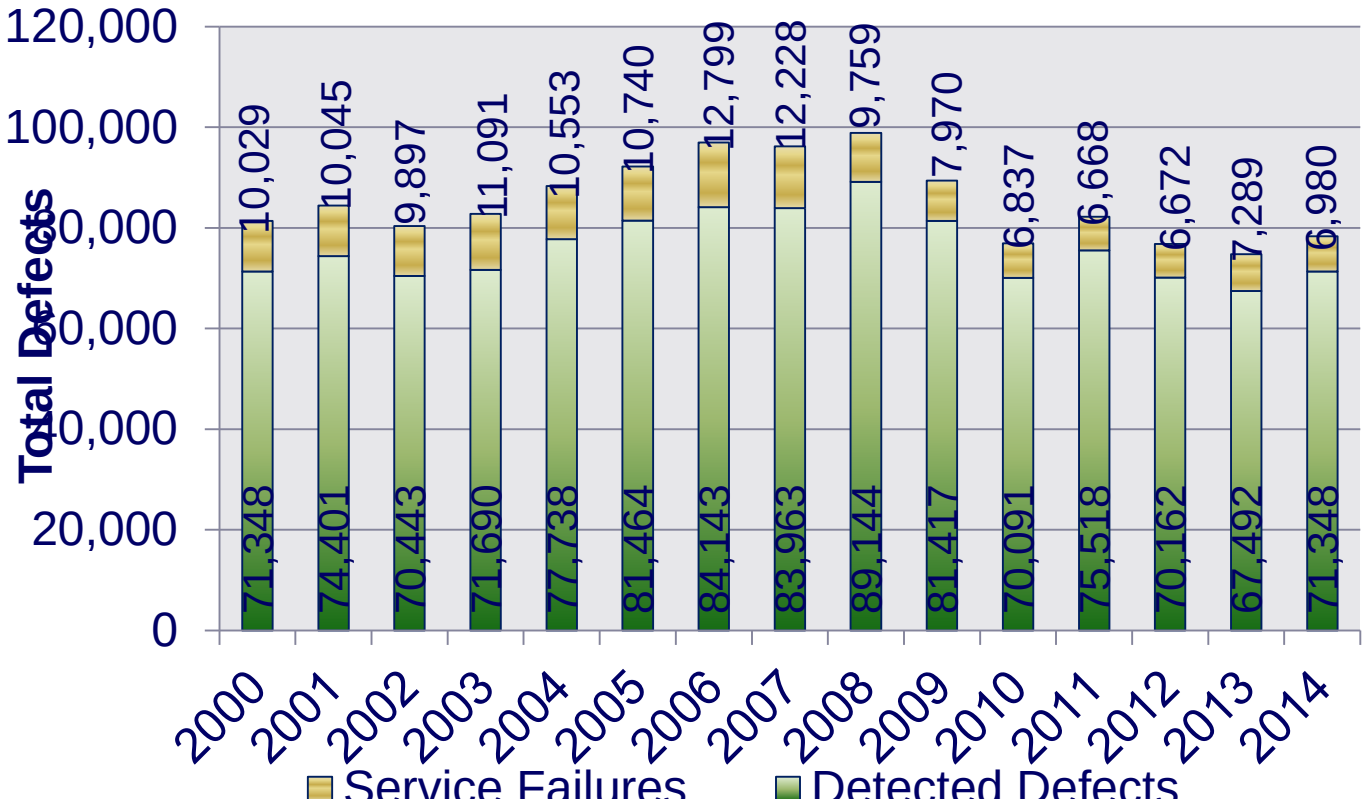
Miles of Rail Tested (2000 – 2014)



Source: (Main Track): BNSF, CSX, KCS, NS, UP, CN (U.S.) and CP (U.S.), FRA Office of Railroad Safety.
Note: Two railroads reported data on ALL track (industry, yard and sidings)

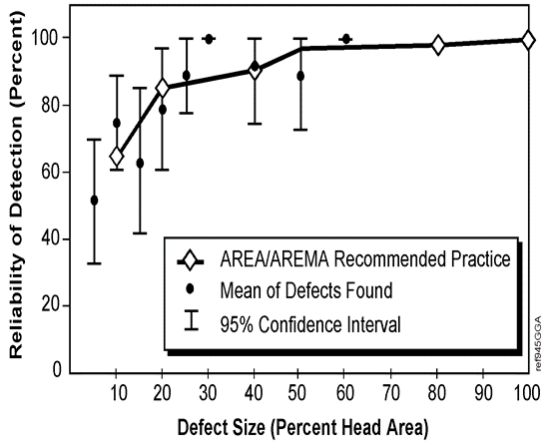
Rail and Weld Defects (2000 – 2014)

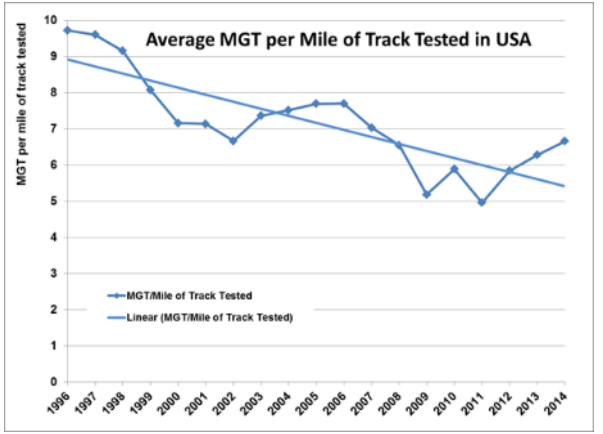
Service Failures and Detected Defects

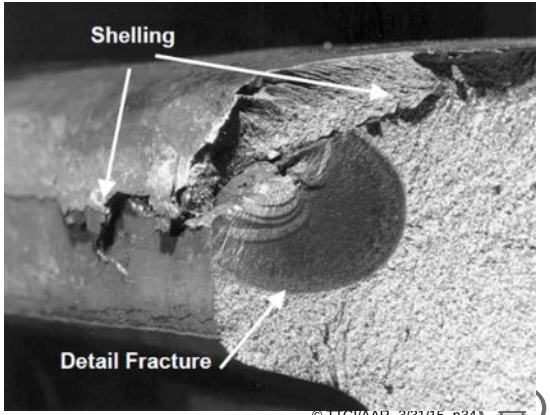


Source: (Main Track): BNSF, CSX, KCS, NS, UP, CN (U.S.) and CP (U.S.).
Note: One railroads reported data on ALL track (industry, yard and sidings) for the reported Detected Defects.

What is the North American Rail Industry Doing to Eliminate Broken Rail Derailments?



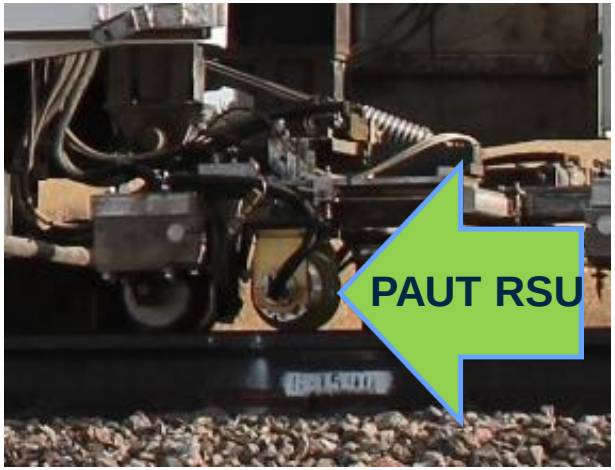


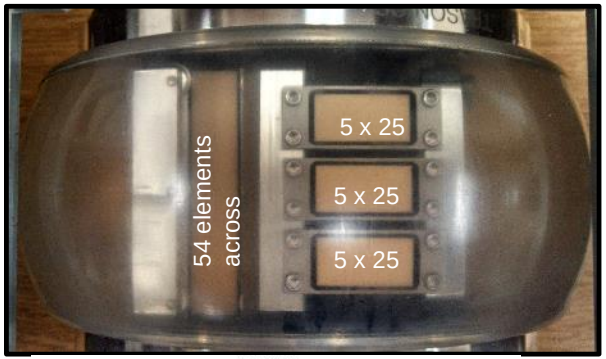


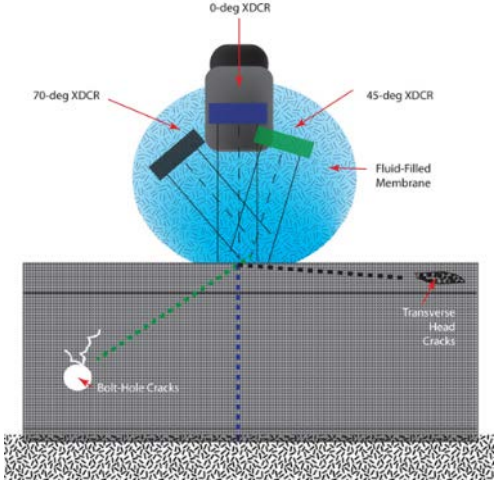
Can we Detect Missed Flaws using New Technology?

Phased Array Rail Inspection

- **Multiple Matrix Phased Array**
  - 20-mph vehicle inspection speed
  - Rail profile compensation
  - High resolution mode
  - Onboard flaw validation
- **Commercialization**







Phased Array Rail Flaw Detection

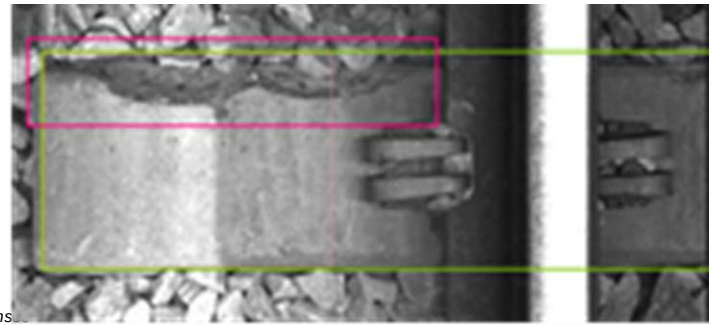
Linear Probe Coverage

Phased Array Angle Beam Inspection Provides full rail head coverage

Phased Array Prototype - Video

Machine Vision Inspection of Track

- **Machine vision inspection systems that target a variety of track elements**



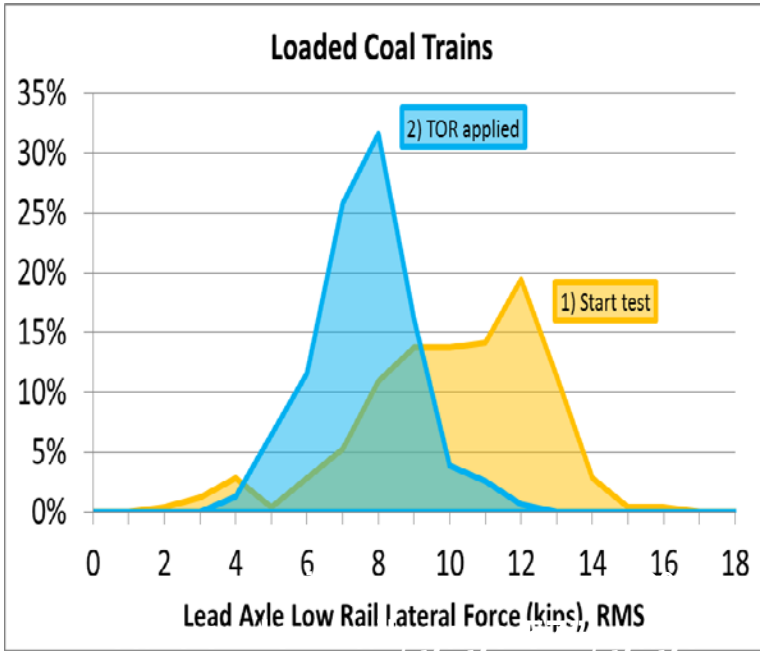
Images courtesy of Ens

Automated Wheel/Rail Contact Inspection System

- **Contact parameters assessed by this system include:**
  - Contact position
  - Contact conicity
  - Contact conformity of outer rail on curves
  - Maximum contact angle
  - Rolling radius difference on curves
  - Contact stress
- **The system can be operated at speeds up to 100 km/h**

Friction control and impact of TOR on lateral forces

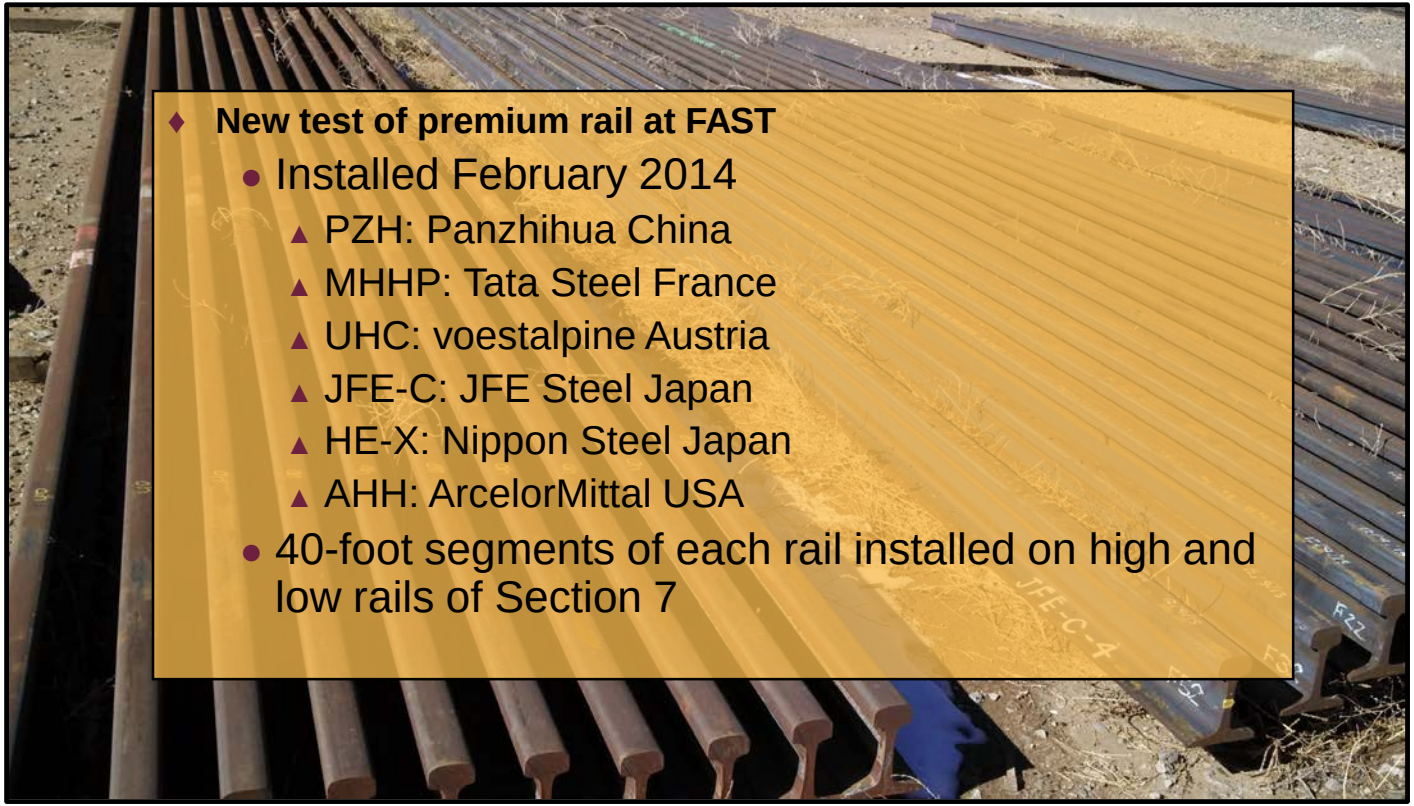
REGION	No. TOR Lubricators	No. GF Lubricators
Western	597	1,131
Southern	12	559
Northern	193	866
TOTAL	**802**	**2,556**



Heavy Axle Load Research at the Facility for Accelerated Service Testing at TTC

- Challenges addressed by this research
  - Enhance understanding of safety, technical and economic impact of heavy axle loads
  - Accelerated testing of the effects of a 17k-ton train on new and untried track components at FAST
  - Operations under computer control
  - Rail technology evaluation test bed
  - Safe implementation of increased axle loads in North America

Currently being tested at FAST



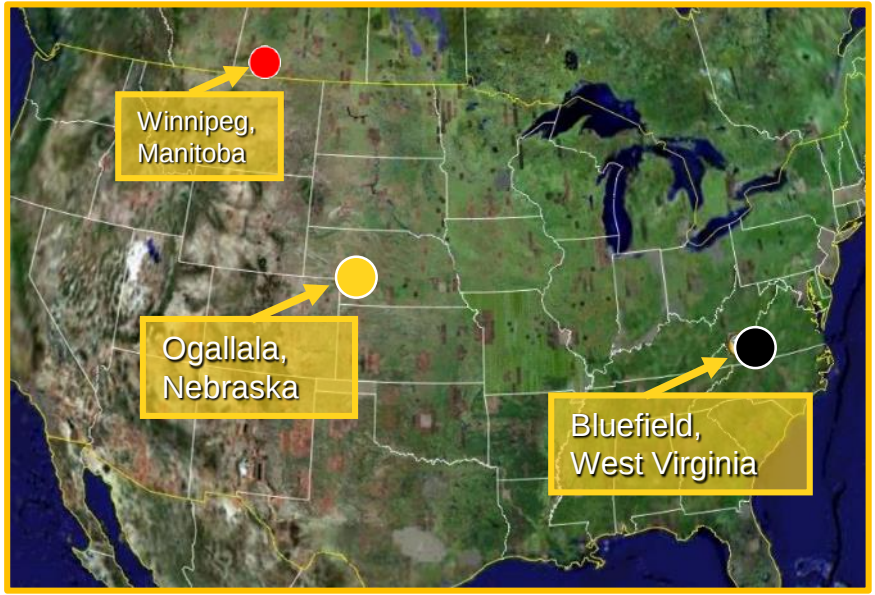
- **New test of premium rail at FAST**
  - Installed February 2014
    - PZH: Panzhihua China
    - MHHP: Tata Steel France
    - UHC: voestalpine Austria
    - JFE-C: JFE Steel Japan
    - HE-X: Nippon Steel Japan
    - AHH: ArcelorMittal USA
  - 40-foot segments of each rail installed on high and low rails of Section 7

Steel Bridge Life Extension
Five Riveted Girder Spans Being Tested

- **Fitness for Service Assessment**
  - Considers a broad spectrum of factors contributing to safe service life
  - Used for aircraft and pipeline industries
  - Encompasses the following:
    - Fatigue evaluation and redundancy
    - Statistical reliability
    - Fracture toughness
- **Advanced Designs and materials**
- **Onboard inspection systems**

Improved Safety and Efficiency Improvements: **Full-scale Track Component Evaluation at FAST and in Revenue Service**

- **Investigate performance of improved track components and maintenance procedures**
  - New rail steels to increase rail wear and fatigue performance
  - Higher strength crossties
  - Advanced special trackwork designs
  - Proof of concept and prototype evaluation of new technologies
  - Track substructure
  - Cold weather effects on track

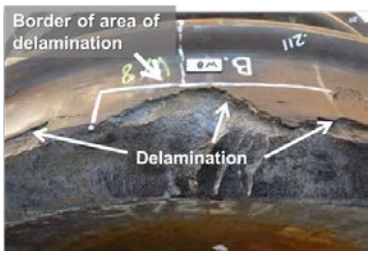


Mitigating the Consequences of Rolling Contact Fatigue (RCF)

- **Challenges Addressed**
  - Wheel/rail line of road failures
    - Reduce/eliminate wheel removals / unscheduled rail grinding
    - Broken wheels/rail failures
- **End Products**
  - High Performance (HP)
    - Materials
    - Design (shape)
    - Manufacturing methods
  - Specifications supporting HP wheel and rail supply in North America

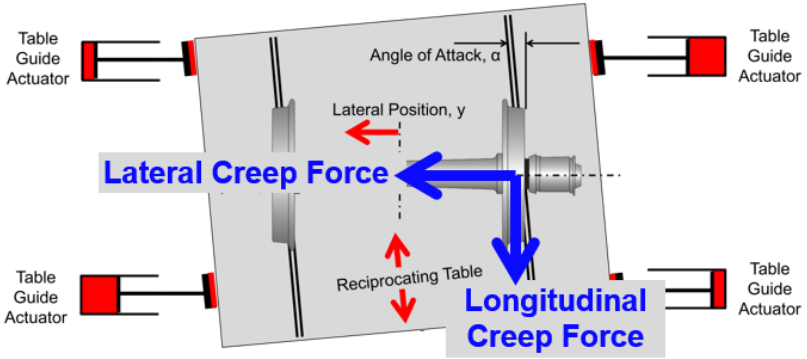
High Impact Wheel

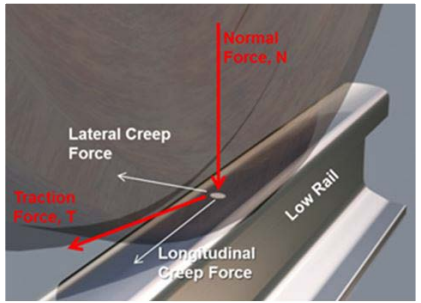
Rail Spalling



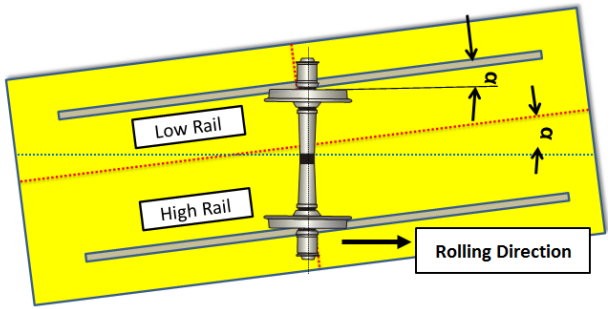
Vertical Split Rim

Simulate Lead Axle, Low Rail, T/N

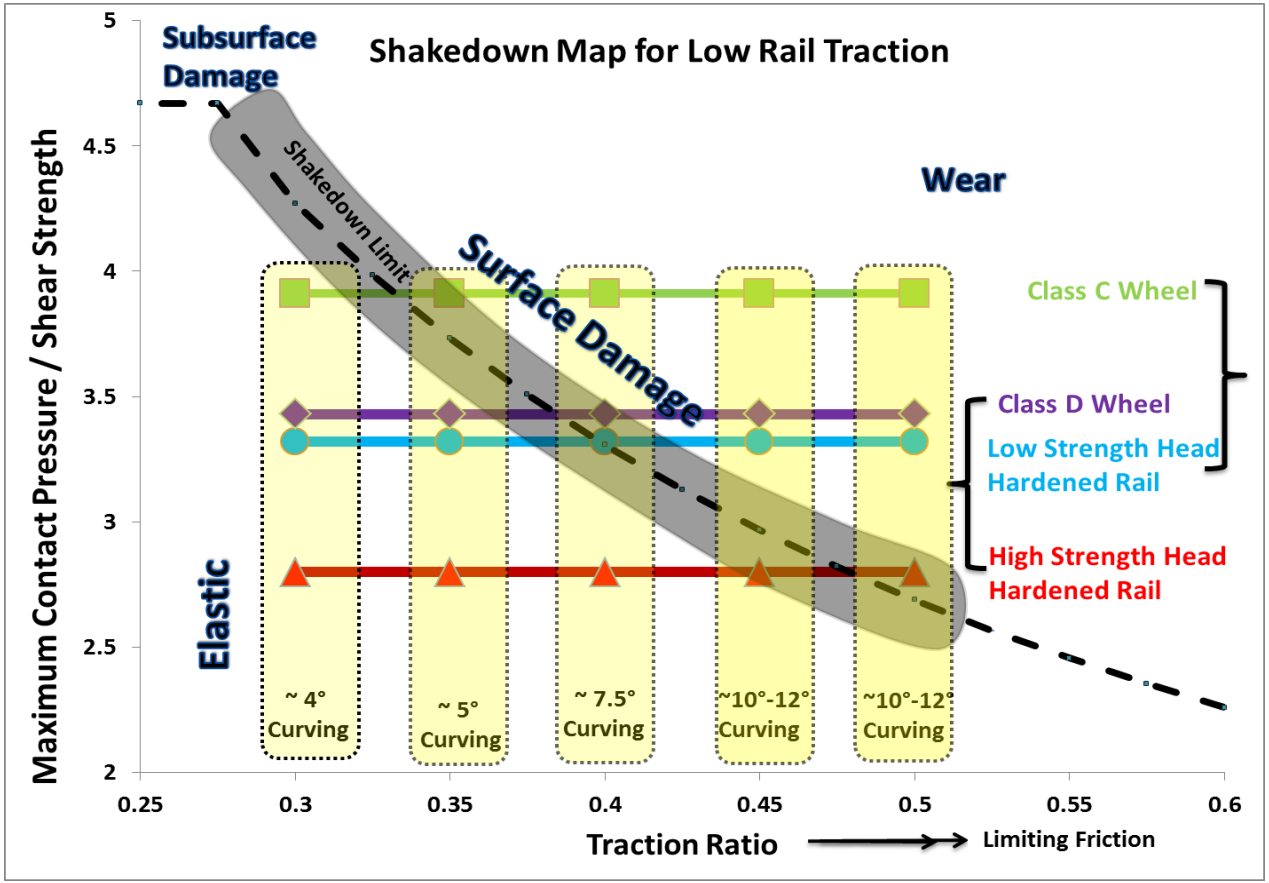




Over-the-Road (IWS) Wheel / Rail Force Data

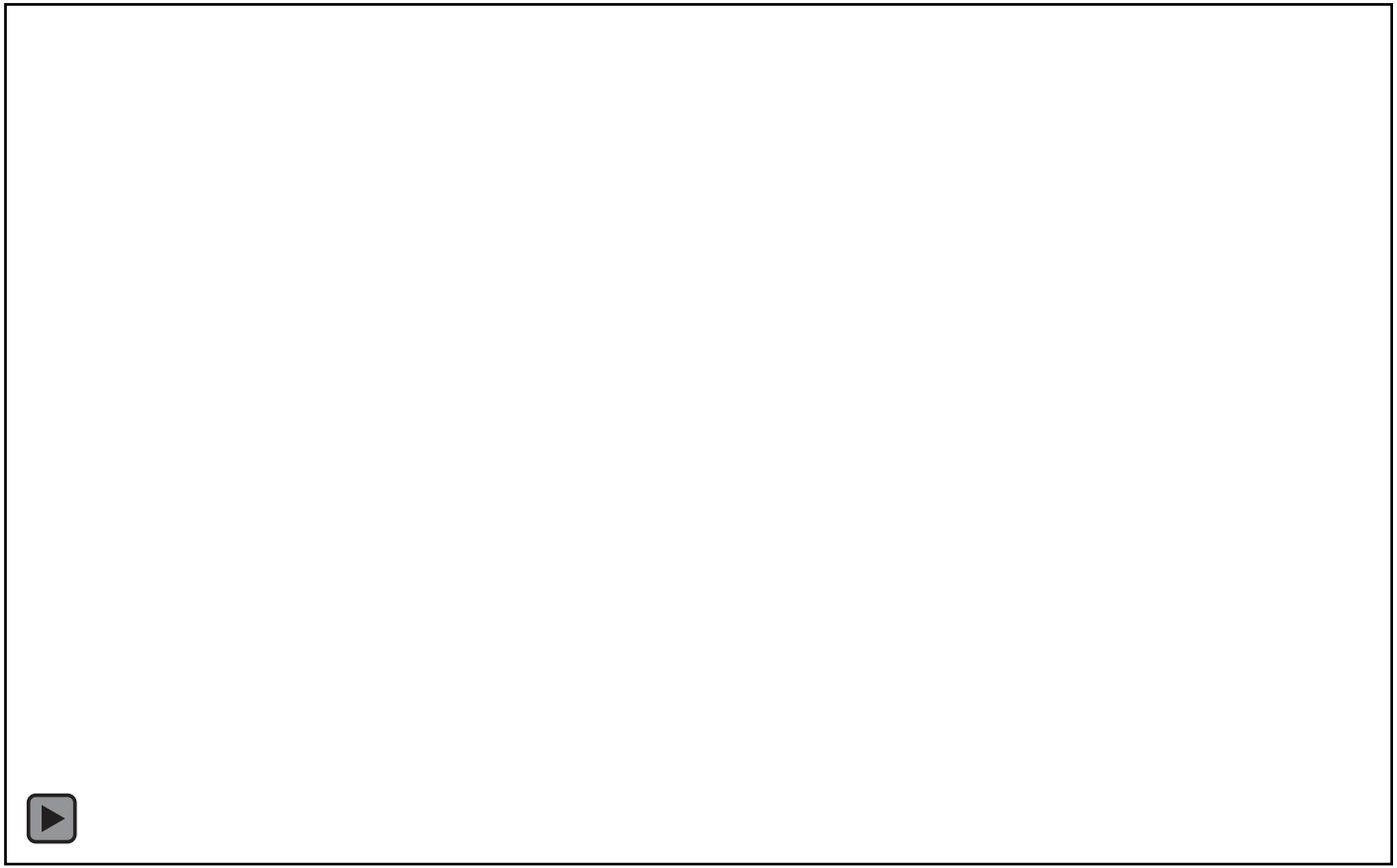


RCFS Test Program



Rolling Contact Fatigue Simulator

RCFS 24-hr Camera Monitoring System

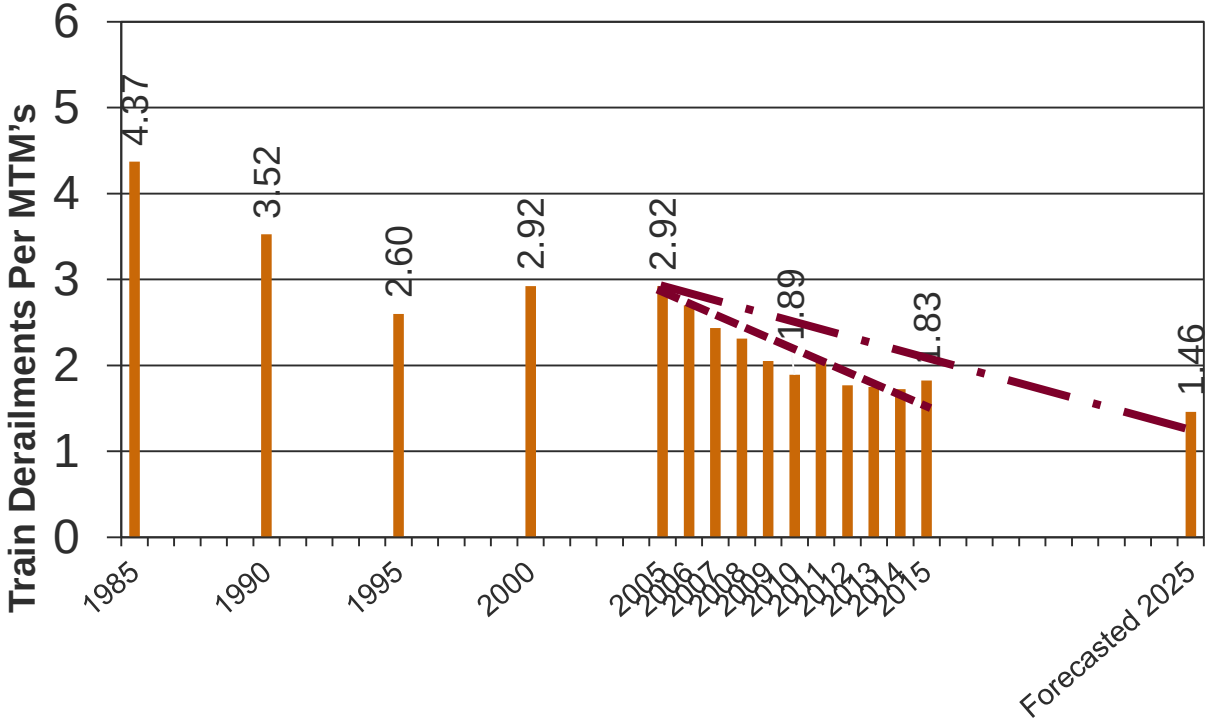


Railway Research Needs

Future Opportunities:

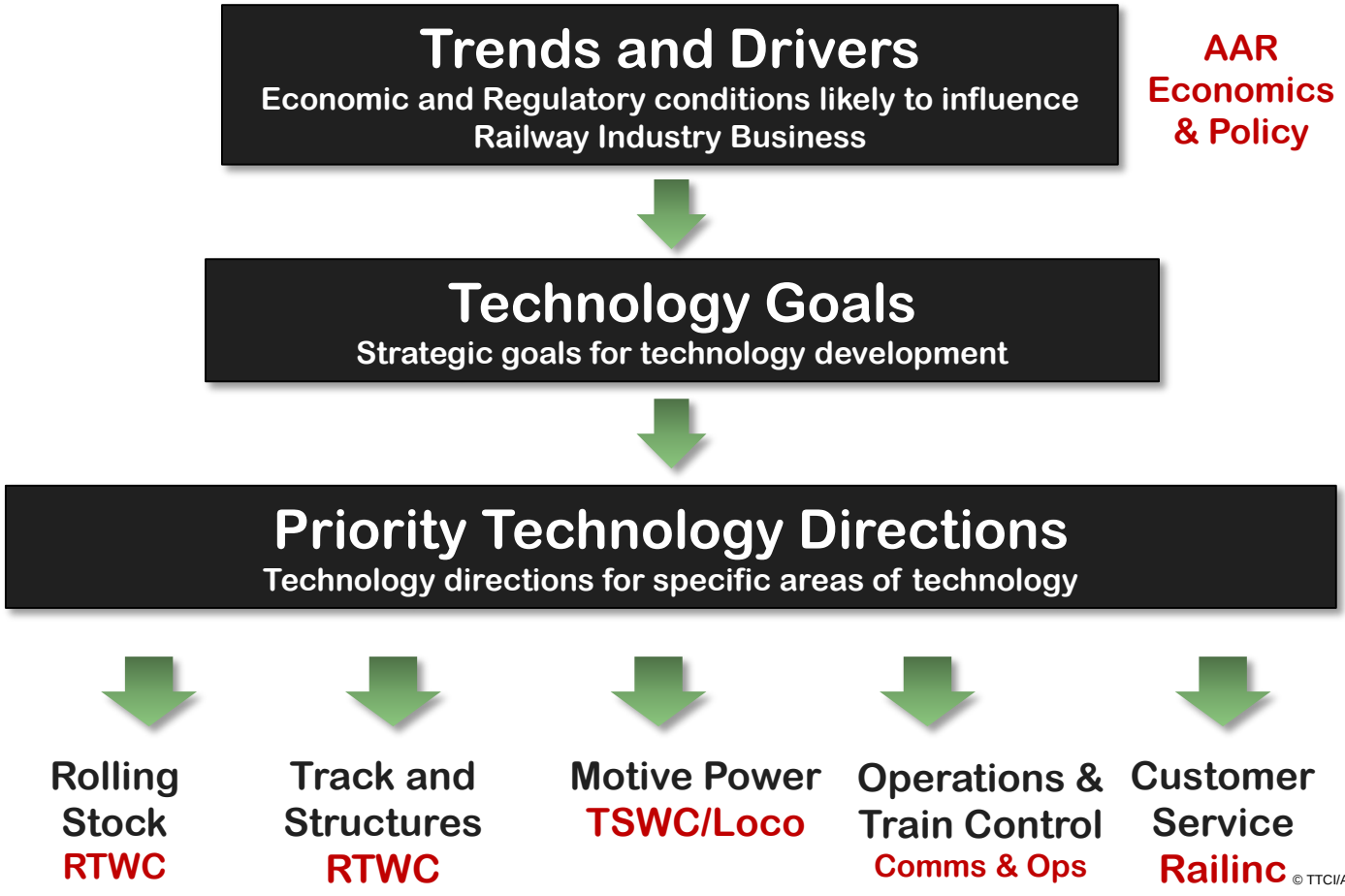
- Machine vision detection of condition changes
- Onboard wagon health inspection
- Drone & Robotic-assisted inspection (UAVs)
- "Big Data Analysis": composite alarms and relational databases and predictive analytics
- Advanced rail flaw inspection systems
- Rail surface condition (RCF) inspection
- Rail longitudinal stress measurement systems
- Track substructure inspection systems
- Friction/lubrication condition measurement systems
- Wood or engineered cross-tie inspection
- Bridge structure inspection (acoustic emissions, etc.)
- Cost effective, contact or non-contact wheel and axle inspection

Train Derailments – Per Million Train Miles (MTM's)
FRA Reported for U.S. Railroads (1985-2015)



Source: FRA Reported Train Derailments (AAR Railroad Facts Book)
Note: 2005-2015 data downloaded 9/6/2016

Technology Roadmap Topical Areas



Technology Development Priorities Rolling Stock: 2015 Update

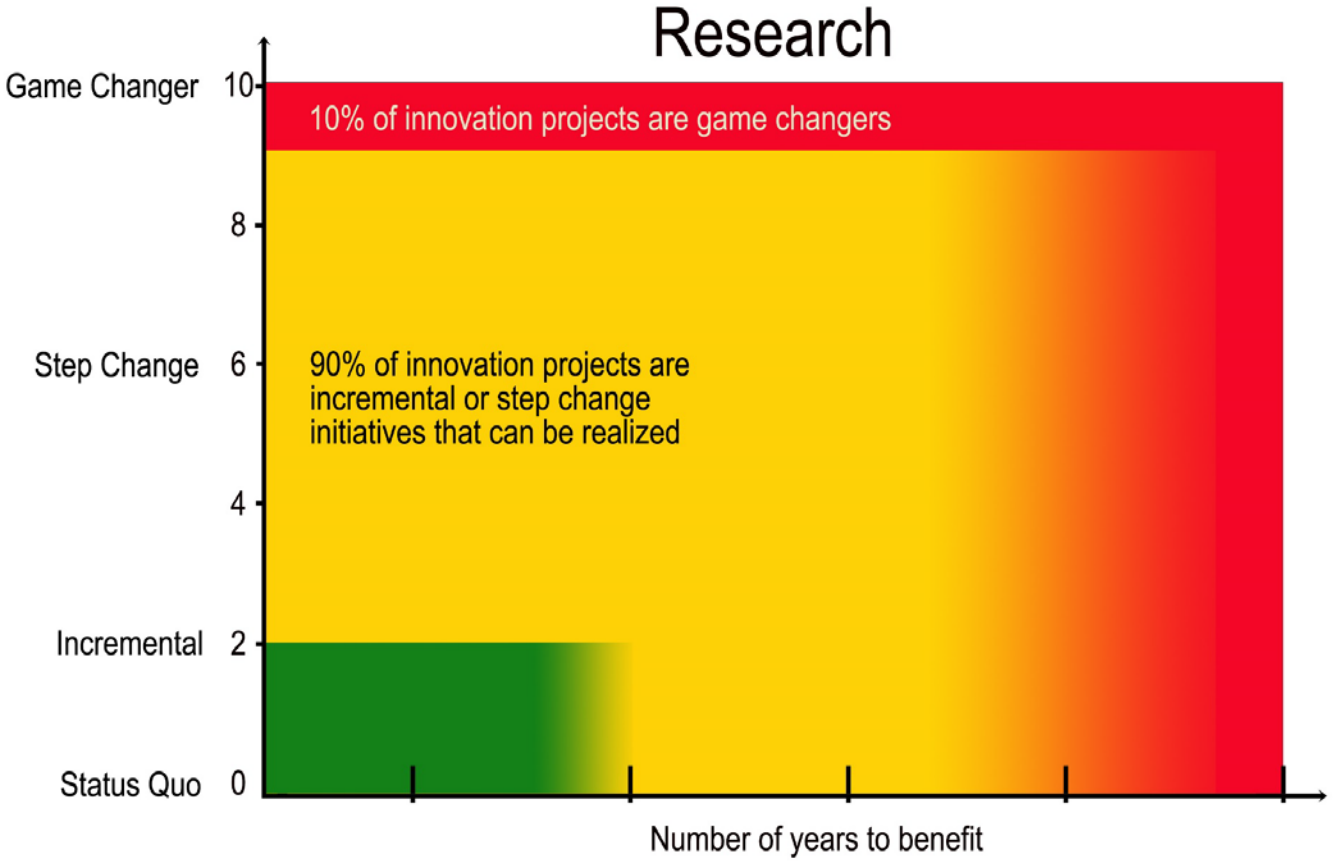
Industry Role	Priority		
	Useful	Necessary	Essential
High		Asset health strategy initiatives Improved asset tracking Unified car and component database Technical Specs for Interoperability and mechanical standards Wheel/rail interface management	Reduced Accidents Automated health monitoring/inspection Reduced in-service failures Next generation tank car and tank car research Increased rolling stock & component life Improved vehicle/track interaction
Medium	Improved braking capability Locomotive technology research Zero reactive maintenance Simplified car design Aerodynamic design	Reduced life-cycle and total system cost Big data analytics Improved car and truck performance Increased car and train capacity, and axle loads Theoretical modelling to give accurate predictions of the minimum life or failure of assets Car and component design for improved / efficient maintenance practices	

Source: "Railroad Industry Priority Technology Goals and Directions for the Next 20 Years"© - Association of American Railroads

Track & Structures : 2015 Update

Industry Role	Priority		
	Useful	**Necessary**	**Essential**
High		Life extension for existing bridges Prevention of track failures for increased reliability Improved signaling and train control Improved track substructure Automated in-track condition monitoring Reduced track component life-cycle cost Longer lasting/cost-effective bridges Reduced component life cycle and total system costs Improved track maintenance	**Accident reduction** **Automated on-board track inspection (including drones and machine vision)** **Improved understanding of long and heavy trains on track structure** **Increased rail life** **Increased axle loads**
Medium	Standard designs of infrastructure The development of intelligent infrastructure maintenance planning Shared use corridors Theoretical modelling to give accurate predictions of the minimum life or failure of assets Sustainable infrastructure development	Improved tie/fastener systems Decreased maintenance cost/ton-mile Improved special trackwork designs and materials Low-impact track Track design for smooth train velocities Big data analytics for inspection analysis and maintenance management Improved track/signal interfaces Training/ technology transfer Standardized wayside detection systems Zero reactive maintenance	

Strategic Research Innovation



Thank you for your support.