“An Overview of AAR Railway Research and Technology Innovation”

Semih Kalay
Senior Vice President, Technology

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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Students welcome and encouraged to attend!
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

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
2016 North American 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
  - Phased Array Rail Inspection
  - Measurement of Rail Longitudinal Forces
  - Onboard Bridge Inspection

**Track Integrity Monitoring**
- Cracked Wheel Detection
- Technology Driven Train Inspection

**Train Condition Monitoring**
- Improved Hot Box Detectors
- Integrated Freight Car Truck
- High Performance Car Couplings
- High Performance Wheel Steels

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

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

Note: Excludes grade crossing accidents. Data is for 2014.
North American Technology Driven Train Inspection

Database (InteRRIS®)

- Wayside Condition Detection
  - Cracked Axle Detector (CAD)
  - Cracked Wheel Detector (CWD)
  - Thermal Scan (TS)
  - Acoustic Bearing Detector (ABD)
  - Low Air hose Detector (LAD)
  - Dragging Equipment Detector (DED)

- Wayside Performance Detection
  - Truck Hunting Detector (THD)
  - Truck Performance Detector (TPD)
  - Wheel Impact Load Detector (WILD)
  - Warm Bearing Trending (WBT)
  - Wheel Temperature Trending (WTT)

- Wayside Machine Vision Inspection
  - Wheel Profile Module (WPM)
  - Brake Shoe Module (BSM)
  - Automated Safety Appliance Inspection System (ASAIS)
  - Automated Inspection of Structural Components (AISC)
  - Fully Automated Train Scanning System (FATS)

Vehicle Health Report in Lieu of Train Inspection
Impact Load Detectors

INSTRUMENTED TRACK SECTION

V = Instrumented Crib
ALD = Auto Location Detector
Blank Crib

60/24" = 144°
56 26" = 130°

EFFECT OF RADIAL RUNOUT ON IMPACT LOADS
O.O.R. Wheels, 100-Ton Loaded Cars

PEAK IMPACT LOAD (kips)

SPEED (mph)

[Graph showing the effect of radial runout on impact loads]

[Images of impact load detectors and track sections]
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
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
Technology Driven Train Inspection

♦ Machine-vision Inspection of Truck Details
  ● Three vendors chosen to demonstrate truck detail inspection modules at FAST
Wheel Profile Measurement

Wheel Profile

Brake Shoe
What is Next for Machine Vision Car Inspection 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

Based on USGS DLG, 1:2,500,000, Geographic Projection, DD.

2015 (c), Transportation Technology Center, Inc.
Implementation of Automated Equipment Health Monitoring & Management

- Wayside systems feed InteRRIS® after identifying the car with AEI
- InteRRIS® identifies a “Stress-State” condition
- InteRRIS® communicates with Railinc Systems for processing
Industry Central Detector Database *(InteRRIS®): 2+ Terabytes of data stored (since 2000)*

<table>
<thead>
<tr>
<th>Incoming From</th>
<th>Outgoing To</th>
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<tbody>
<tr>
<td>♦ 300+ wayside detectors reporting</td>
<td>♦ Carriers</td>
</tr>
<tr>
<td>♦ ≈ 4,300 trains/day</td>
<td>♦ Private Car Owners</td>
</tr>
<tr>
<td>♦ ≈ 400,000 vehicles/day</td>
<td>♦ Shops\Fleet Managers</td>
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<tr>
<td>♦ ≈ 470,000,000 records/month</td>
<td>♦ 3rd Party Services</td>
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<td>♦ Manufacturers</td>
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<td>♦ Industry System (EHMS)</td>
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<thead>
<tr>
<th>Incoming</th>
<th>Outgoing</th>
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<tbody>
<tr>
<td>♦ 50+ outbound datafeeds</td>
<td>♦ 1.7 million vehicles monitored</td>
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<tr>
<td>♦ 1.7 million vehicles monitored</td>
<td>♦ 1600+ daily event notification messages</td>
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<tr>
<td>♦ ≈ 4,300 trains/day</td>
<td>♦ ≈ 400,000 vehicles/day</td>
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<tr>
<td>♦ ≈ 470,000,000 records/month</td>
<td>♦ ≈ 470,000,000 records/month</td>
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</tbody>
</table>
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

Images courtesy of RailPictures.net
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 railroad 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 Ensco
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

<table>
<thead>
<tr>
<th>REGION</th>
<th>No. TOR Lubricators</th>
<th>No. GF Lubricators</th>
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<tbody>
<tr>
<td>Western</td>
<td>597</td>
<td>1,131</td>
</tr>
<tr>
<td>Southern</td>
<td>12</td>
<td>559</td>
</tr>
<tr>
<td>Northern</td>
<td>193</td>
<td>866</td>
</tr>
<tr>
<td>TOTAL</td>
<td>802</td>
<td>2,556</td>
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**Loaded Coal Trains**

- **1)** Start test
- **2)** TOR applied
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
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

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

- Winnipeg, Manitoba
- Ogallala, Nebraska
- Bluefield, West Virginia
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
Simulate Lead Axle, Low Rail, T/N

Lateral Creep Force

Longitudinal Creep Force

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

Shakedown Map for Low Rail Traction

Elastic

Maximum Contact Pressure / Shear Strength

Subsurface Damage

Surface Damage

Wear

Class C Wheel

Class D Wheel

Low Strength Head

Hardened Rail

High Strength Head

Hardened Rail

Traction Ratio

Limiting Friction

~4° Curving

~5° Curving

~7.5° Curving

~10°-12° Curving

~10°-12° Curving
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)

Source: FRA Reported Train Derailments (AAR Railroad Facts Book)
Technology Roadmap Topical Areas

Trends and Drivers
Economic and Regulatory conditions likely to influence Railway Industry Business

Technology Goals
Strategic goals for technology development

Priority Technology Directions
Technology directions for specific areas of technology

Rolling Stock RTWC
Track and Structures RTWC
Motive Power TSWC/Loco
Operations & Train Control Comms & Ops
Customer Service Railinc

AAR Economics & Policy
## Technology Development Priorities Rolling Stock: 2015 Update

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

<table>
<thead>
<tr>
<th>Industry Role</th>
<th>Priority</th>
<th>Essential</th>
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</thead>
</table>
| **High**      | Asset health strategy initiatives  
Improve 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 |
## Track & Structures: 2015 Update

<table>
<thead>
<tr>
<th>Industry Role</th>
<th>Priority</th>
<th>Useful</th>
<th>Necessary</th>
<th>Essential</th>
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<tr>
<td><strong>High</strong></td>
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<tr>
<td></td>
<td><strong>Useful</strong></td>
<td>Life extension for existing bridges</td>
<td>Prevention of track failures for increased reliability</td>
<td>Accident reduction</td>
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<td>Improved signaling and train control</td>
<td>Improved track substructure</td>
<td>Automated on-board track inspection (including drones and machine vision)</td>
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<td>Automated in-track condition monitoring</td>
<td>Reduced track component life-cycle cost</td>
<td>Improved understanding of long and heavy trains on track structure</td>
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<td>Longer lasting/cost-effective bridges</td>
<td>Reduced component life cycle and total system costs</td>
<td>Increased rail life</td>
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<td>Improved track maintenance</td>
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<td>Increased axle loads</td>
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<td><strong>Medium</strong></td>
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<td>Standard designs of infrastructure</td>
<td>Improved tie/fastener systems</td>
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<td>The development of intelligent infrastructure maintenance planning</td>
<td>Decreased maintenance cost/ton-mile</td>
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<td>Shared use corridors</td>
<td>Improved special trackwork designs and materials</td>
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<td>Theoretical modelling to give accurate predictions of the minimum life or failure of assets</td>
<td>Low-impact track</td>
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<td>Sustainable infrastructure development</td>
<td>Track design for smooth train velocities</td>
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<td>Big data analytics for inspection analysis and maintenance management</td>
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<td>Improved track/signal interfaces</td>
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<td>Training/ technology transfer</td>
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<td>Standardized wayside detection systems</td>
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<td>Zero reactive maintenance</td>
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10% of innovation projects are game changers

90% of innovation projects are incremental or step change initiatives that can be realized
Thank you for your support.