



Technology Driven Train Inspection

Presented to

*Mechanical Association
Railcar Technical Services*

Chicago
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Outline



- ◆ Introduction
- ◆ Background
- ◆ Technology Driven Train Inspection (TDTI)
- ◆ Wheel Condition Monitoring
- ◆ FactIS™
- ◆ Acoustic Bearing Defect Detection
- ◆ Wayside Truck Performance Detection
- ◆ InteRRIS™
- ◆ Wayside Cracked Wheel Detection
- ◆ Wayside Cracked Axle Detection
- ◆ The Future





Introduction

- ◆ **Railroad fleets require inspection, maintenance, & repair**
- ◆ **Ensuring rolling stock receives maintenance prior to service degradation or interruption is challenging task**
- ◆ **Railroads incorporate new techniques and technologies for more complete, effective, and efficient inspections**
- ◆ **Emerging technology applications have recently been adapted to railway use in automating inspection of moving rail cars from wayside or trackside locations**





Background

- ◆ **Systems Used For Many Years**
 - Hot Bearing Detectors (HBD)
 - Wheel Impact Load Detectors (WILD)
 - Dragging Equipment Detectors (DED)
 - Hot Wheel Detector (HWD)
 - Cold Wheel Detector (CWD)

- ◆ **Recently Deployed Technologies – last 6-8 yrs**
 - Truck Performance Detector (TPD)
 - Acoustic Bearing Detector (ABD)
 - Truck Hunting Detector (THD)
 - High Speed Video Imaging (HSVI)





Background (continued)

Several Technologies On Near Horizon

- ◆ **Newer Wheel Profile Monitoring (WPM) systems**
- ◆ **Newer Truck Hunting Detection (THD) systems**
- ◆ **Laser Ultrasonic based wheel and axle inspection systems**
 - **Cracked Wheel Detector (CWD)**
 - **Cracked Axle Detector (CAD)**





Purpose of TDTI

Improve productivity, safety, & customer satisfaction

- ◆ **Railways have progressively moved away from emergency & reactive repairs to planned & scheduled component replacement**
- ◆ **Increasingly look to technology to assist in managing their rolling stock assets (cost reduction, damage prevention, & equipment use)**
- ◆ **Last 25 yrs, US railways doubled revenue freight ton-miles & reduced freight car fleet by 23 % and employment by 58 %**
- ◆ **Improved inspection systems have played an significant role in productivity improvements**
- ◆ **Customer service & satisfaction a key driver and an essential benefit from using Technology Driven Train Inspection (TDTI)**

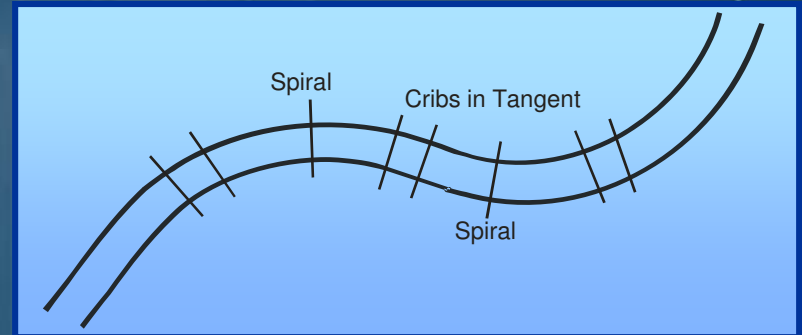




TDTI – Deployed Technologies

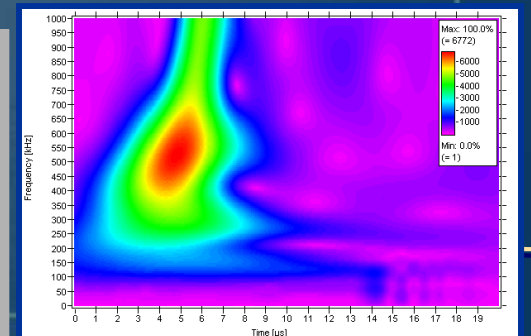
- ◆ **Thermal**
 - Hot Bearing Detection
 - Hot Wheel Detection

- ◆ **Strain Gauge-based**
 - Wheel Impact
 - Overload & Imbalanced Load
 - Truck Performance
 - Hunting



TDTI – Newer Technologies

- ◆ Image-Based
 - Wheel Profile
 - Missing, Worn or Damaged Components
 - Hunting
- ◆ Sensor-based Truck Hunting
- ◆ Acoustic
 - Acoustic Bearing Detection
 - Leaking Air Sensors
- ◆ Ultrasonic
 - Cracked Wheel
 - Cracked Axle





Economic Benefits of TDTI

- ◆ **Investments in TDTI must compete for limited capital funds**
- ◆ **TTCI has performed a number of extensive cost/benefit studies for the North American railroad industry**
- ◆ **Usually, ROI calculation based on benefit streams from safety, improved asset utilization, cost avoidance, and improved customer satisfaction**
- ◆ **Example - WILD cost/benefit study**
 - **Considered trade-off between early removal of wheel sets (loss of remaining life) and reduced damage to track**
 - **Economic benefit of removing high impact wheels using WILD technology in the U.S. railway industry is in excess of \$40 million per year**



TDTI Must Address Inspection Requirements

- ◆ In US, 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)
- ◆ Railroads abide by CFR49 rules by conducting pre-departure (outbound) inspections
- ◆ For efficiency many 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





TDTI Targets Of Opportunity

- ◆ **HSVI to determine wheel & brake system conditions appear to provide most immediate benefit**
- ◆ **Wheel Info:** flange height & thickness, rim thickness, and wheel hollow wear
- ◆ **Brake System Info:** 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





Desired TDTI System Attributes

- ◆ **Easy installation**
 - **No operational disruption**
 - **No hindrance to maintenance operations**
- ◆ **Low maintenance requirements**
- ◆ **Long service life / durability**
- ◆ **Accurate, repeatable data**
- ◆ **Useful inspections for actionable maintenance**
- ◆ **Solid return on investment**





TDTI - Wheel Condition Monitoring

- **Systems based on HSVI & laser technologies**
- **Currently available wheel profile measurement systems**
 - **AEAT/Alstom Treadview™ System**
 - **BeenaVision WP System**
 - **Hegenscheidt ARGUS**
 - **Imagemap WheelSpec™ System**
 - **KLD WheelScan**
 - **TTCI FactIS™**



AEAT/Alstom TreadView™ System



- System installed at Longsight Traincare Depot in Manchester, UK
- Wheel Profile Measurement Parameters
 - Flange Thickness
 - Flange Height
 - Rim Thickness





BeenaVision Wheel Profile System



- ◆ **System installed at TTC's FAST track & evaluated in late 03 & early 04 – results looked promising**
- ◆ **Wheel Profile Measurement Parameters**
 - **Flange Thickness**
 - **Flange Height**
 - **Rim Thickness**
 - **Tread Hollow**



Hegenscheidt - ARGUS

- ◆ **Diagnostic system for inspecting wheelsets on a moving train**
- ◆ **Monitors wheelset tolerances and operating deviations**
- ◆ **Improves safety, travelling comfort & operational reliability.**
- ◆ **Automatic, precise and fast measuring operation**
 - **Provides wear forecast**
 - **Increases vehicle availability by monitoring wheelset wear**



ImageMap WheelSpec System



- ◆ Hi-Speed Wheel Profile Systems for Mainline Measurement of Wheel Profiles and Wheel Gauge at Speeds up to 100 km/h
- ◆ Lo-Speed Wheel Profile Systems for Yard and Depot use. High Accuracy Measurement for Equivalent Conicity Calculations
Measurement of Out-of round and Wheel Flats
- ◆ Database Systems for Wheel Fleet Data Management





KLD Labs - WheelScan System



- ◆ **Uses a combination of lasers and video cameras to profile and measure the wheel**
- ◆ **Acquires video images of the wheel profile and performs dimensional measurements and identification in real-time**
- ◆ **Information compared to railway's wheel criteria for exception reporting. Easily integrated with other wayside instrumentation for comprehensive wheel analysis**



Teknis Wheel Condition Monitor (WCM)



- ◆ Provides in-motion weighing, load pattern analysis, wheel defect classification, automatic vehicle identification, hot-box, bogie geometry, wheel profiles and lateral vehicle tracking.
- ◆ Hybrid system of accelerometers and strain gauges to provide both static and dynamic data
- ◆ Linked to user-defined alarms and automatic report generation
- ◆ Evaluates total damage potential of a wheel





Wheel Impact Load Detectors

1.5 x 5 in. Shell, 106 k

Electronic Equipment





FactIS™ Product Vision

- ◆ **Implement an inspection and information system that provides major efficiencies in allowing railroads to achieve compliance with government safety regulations and industry maintenance standards**

- ◆ **The vision advocates a long-term approach of developing sufficient numbers of inspection modules to replace all inspections currently conducted by yard inspectors**
 - **A system of integrated sensors that can duplicate inspections required under CFR49 Parts 215, 231, and 232**

 - **System must provide data that can be used in lieu of the manual inspection requirements**





CN FactIS™ During Checkout





FactIS™ - Wheel Profile Module

- ◆ Cameras and flashlamps mounted between rails inspect wheels as they pass
- ◆ Triggered by wheel sensors clamped to field side of rail





Strobe Lights & Trigger Boxes



Synchronized for video frame capture clarity

Clarity independent of site lighting conditions





Computers & Support Electronics For Wheel Profile & Brake Shoe Modules



TM



Wheel Flange Video Capture at 60 mph

© Lynxrail. 2004-12-30 13-25 (2) CTRN 601520_Flange Right 1

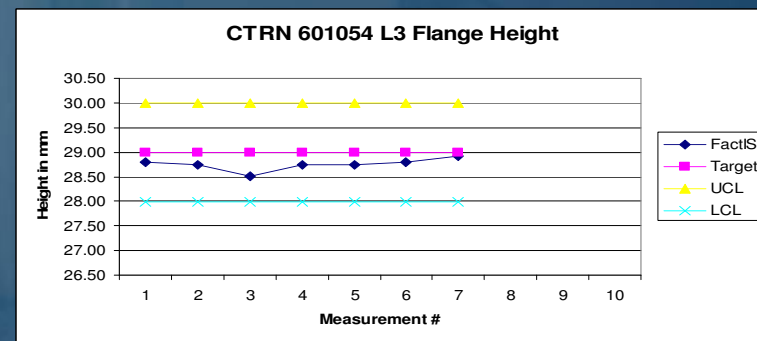
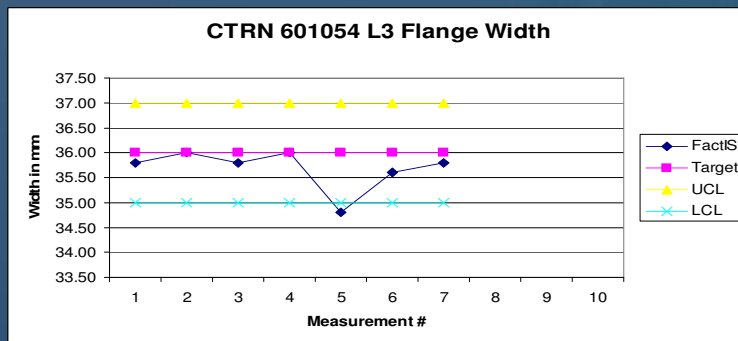
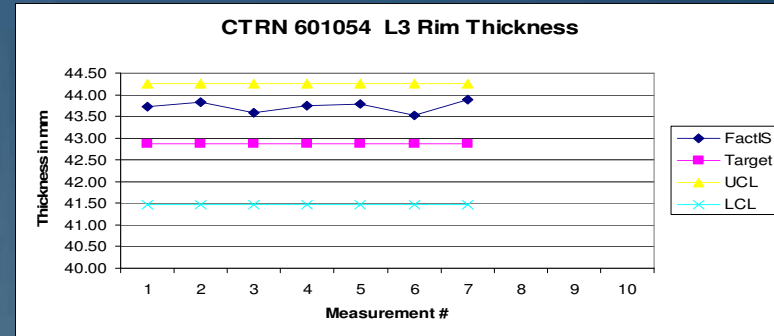
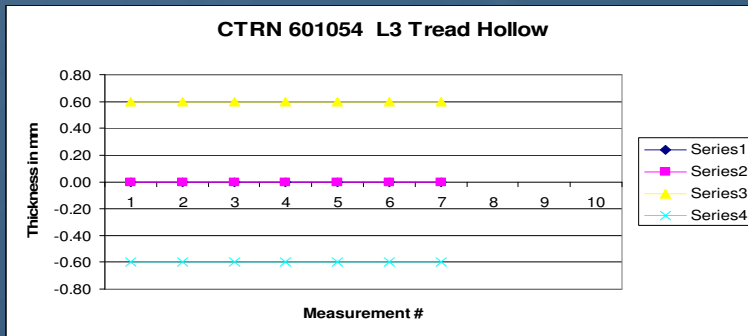


Capabilities:

- Flange height
- Flange thickness
- Flange angle
- Rim thickness
- Tread hollow
- Back-to-back
- Differential diameter



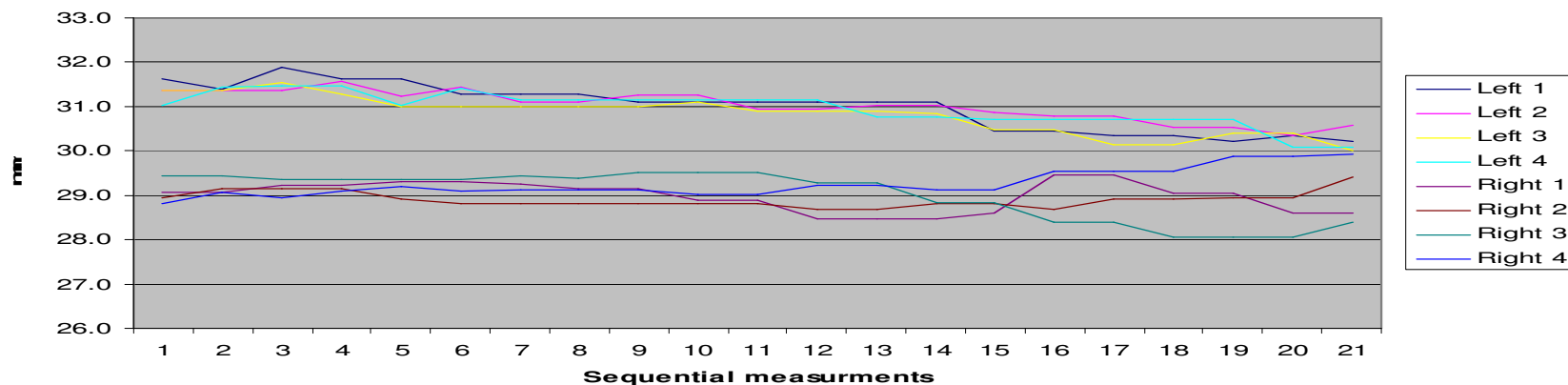
WPM Data Repeatability



Example of Measurement Repeatability

Train Date	Car Type Sequence	Number Plate	Left 1	Left 2	Left 3	Left 4	Right 1	Right 2	Right 3	Right 4
2005-05-15 22-30 [25]	97	1987	31.6	31.4	31.4	31.0	29.1	28.9	29.4	28.8
2005-05-16 14-41 [18]	97	1987	31.4	31.4	31.4	31.4	29.1	29.1	29.4	29.1
2005-05-18 14-12 [10]	202	1987	31.9	31.4	31.5	31.5	29.2	29.1	29.4	28.9
2005-05-19 03-45 [5]	97	1987	31.6	31.6	31.3	31.5	29.2	29.1	29.4	29.1
2005-05-20 00-17 [1]	97	1987	31.6	31.2	31.0	31.0	29.3	28.9	29.4	29.2
2005-05-22 02-00 [3]	97	1987	31.3	31.4	31.0	31.4	29.3	28.8	29.4	29.1
2005-05-23 00-45 [2]	97	1987	31.3	31.1	31.0	31.1	29.3	28.8	29.4	29.1
2005-05-23 06-26 [10]	97	1987	31.3	31.1	31.0	31.1	29.2	28.8	29.4	29.1
2005-05-24 04-25 [6]	97	1987	31.1	31.3	31.0	31.1	29.2	28.8	29.5	29.1
2005-05-24 13-34 [19]	202	1987	31.1	31.3	31.1	31.1	28.9	28.8	29.5	29.0
2005-05-25 04-49 [6]	202	1987	31.1	30.9	30.9	31.1	28.9	28.8	29.5	29.0
2005-05-25 10-34 [16]	198	1987	31.1	30.9	30.9	31.1	28.5	28.7	29.3	29.2
2005-05-27 10-37 [16]	11	1987	31.1	31.0	30.9	30.8	28.5	28.7	29.3	29.2
2005-05-28 05-03 [7]	112	1987	31.1	31.0	30.9	30.8	28.5	28.8	28.8	29.1
2005-05-28 20-57 [33]	222	1987	30.5	30.9	30.5	30.7	28.6	28.8	28.8	29.1
2005-05-29 18-22 [23]	299	1987	30.5	30.8	30.5	30.7	29.5	28.7	28.4	29.6
2005-05-30 11-21 [15]	97	1987	30.3	30.8	30.1	30.7	29.5	28.9	28.4	29.6
2005-05-31 05-49 [7]	97	1987	30.3	30.5	30.1	30.7	29.0	28.9	28.1	29.6
2005-05-31 14-15 [17]	97	1987	30.2	30.5	30.4	30.7	29.0	29.0	28.1	29.9
2005-06-01 08-40 [11]	97	1987	30.3	30.3	30.4	30.1	28.6	29.0	28.1	29.9
2005-06-02 08-02 [10]	97	1987	30.2	30.6	30.0	30.1	0.0	29.4	28.4	29.9

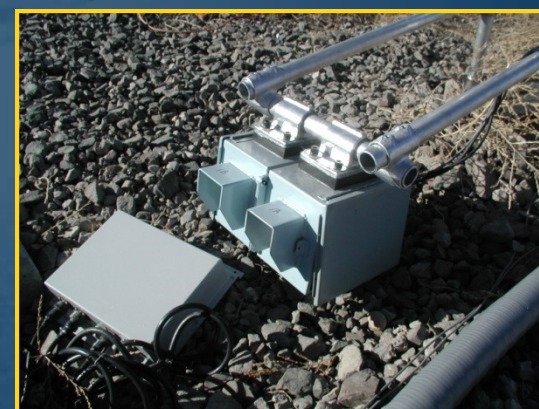
Flange Hight for Car No 1987





FactIS™ - Brake Shoe Module

Cameras & flashlamps attached to masts in way-side track area inspect brake shoes as train passes



TM





Brake Shoe Captures at 60 MPH

© Lynxrail. 2004-12-30 13-25 (2) CTRN 601520 Brake Pad Top Right 2



- Top brake shoe thickness
- Bottom shoe thickness
- Loco wheel witness groove

- Broken brake shoe
- Missing brake shoe

© Lynxrail. 2004-12-30 13-25 (2) CTRN 601520 Brake Pad Bottom Right 2

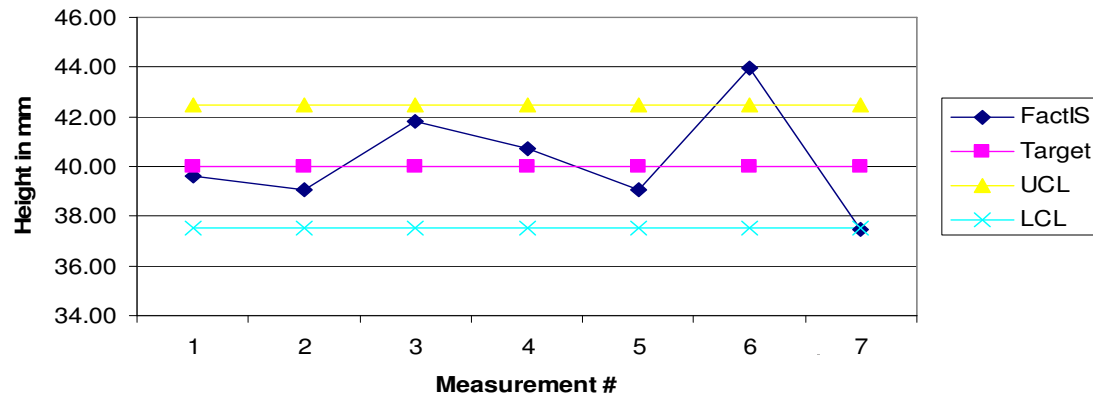


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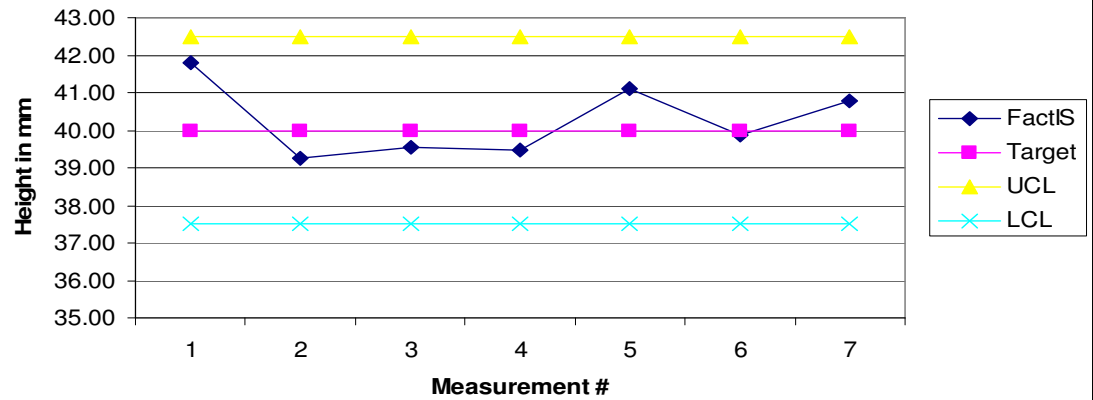


BSM Data Repeatability

CTRN 601054 L2 Brake Shoe Top



CTRN 601054 L2 Brake Shoe Bottom





Bearing Adaptor Module



Bearing Adaptor Info

Determines bearing adapter position & condition

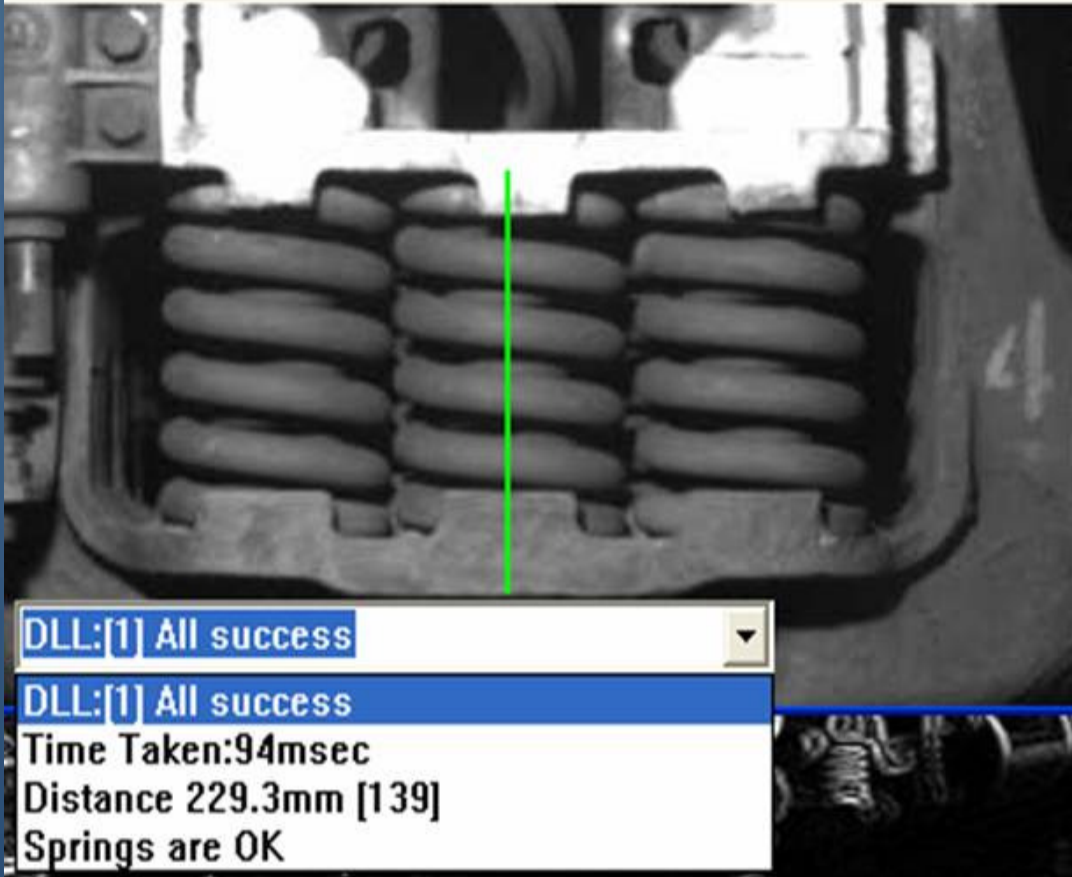
Also examines bearing end cap & bolts



Leaning Loads Module

SPRA 24-06-2003 T01 Car012-05-08 2573.jpg

File Video Measure Tools Reprocessing

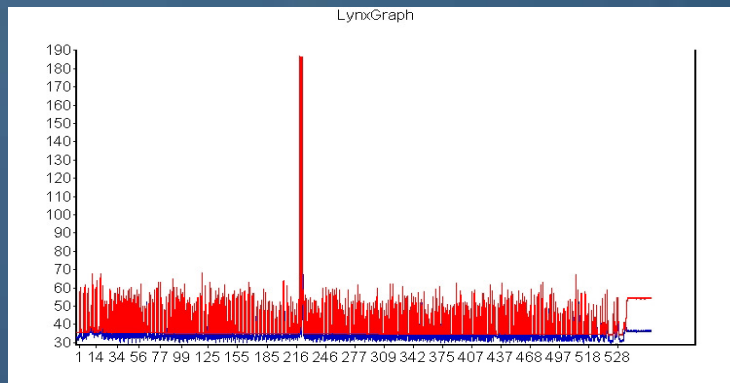


- Leaning loads
- Imbalanced loads
- Differential spring height used to detect leaning / imbalanced loads
- Spring condition



Thermal Scan module

- ◆ Scans for sticking brakes and hot bearings



Detects hot wheel/bearing & identifies axle of concern

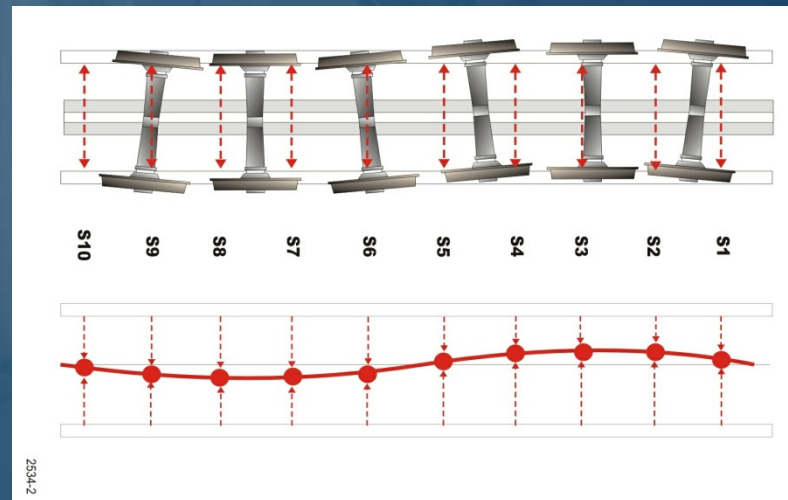


Displays image with – in this case a worn off brake



Truck Hunting Module

- ◆ Paired inductive proximity sensors detect lateral position & AOA of wheelsets
- ◆ Path through array of paired sensors determined
- ◆ Data checked for hunting characteristics





FactIS™ Systems Status*

- ◆ **NS Installation – 30 to 35 mph system**
 - Includes Wheel Profile Module
 - Installed at Eggleston, VA

- ◆ **BNSF Installation – 30 to 35 mph system**
 - Includes Wheel Profile & Brake Shoe Modules
 - System assembled & checked out at TTCI in Dec
 - System installed at Alliance, Nebraska

- ◆ **CN Installation – 60 mph system**
 - Includes High Speed Wheel Profile & Brake Shoe Modules
 - System assembled & checked out at TTCI in Dec
 - Installed at Stony Plain, Alberta, Canada

*Work continues on full impact, weather, & environmental hardening for severe revenue service





Acoustic-Based Bearing Defect Detection

- ◆ **Roller bearing defects can have catastrophic results. The rail industry in North America has taken strong measures to both mitigate and prevent bearing failures. Yet there is a persistent number of failures that occur each year.**
- ◆ **Acoustic bearing detection is designed to provide a means of monitoring roller bearings and identifying those with internal defects prior to overheating, costly train stops, and ultimately failure.**



Bearing Inspections Typical Defects





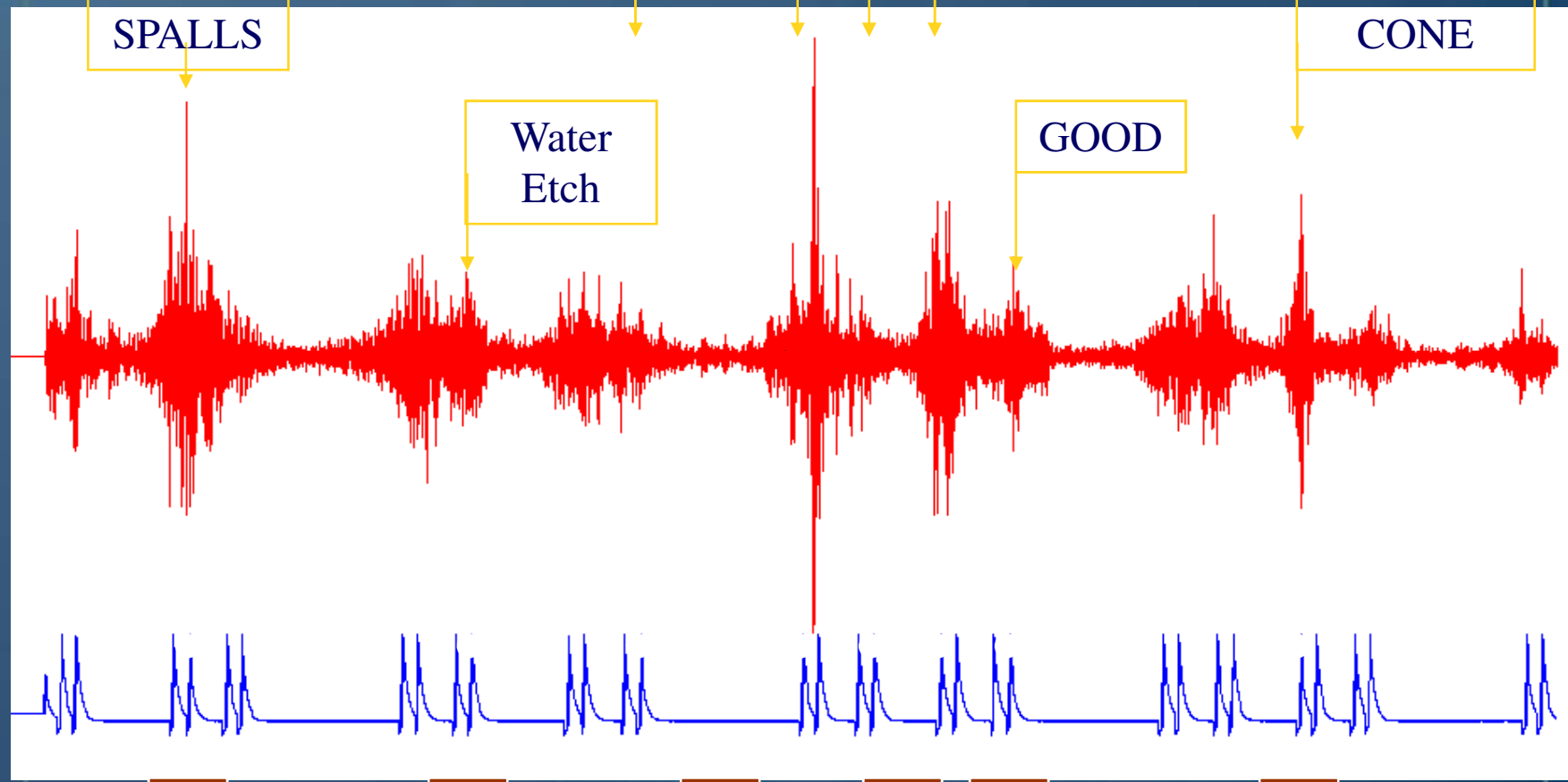
CUP
SPALLS

SPUN CONES

SPALLED
CONE

Water
Etch

GOOD



4



10



14

15



18 - 19



22



27





Vipac RailBAM®



- ◆ Collects acoustic bearing fault & wheel flat data for trains at 'steady' speeds of 30 to 120 kph
- ◆ Identifies and ranks faults in underway rolling stock
 - Running Surface faults - spalls, water etching, brinnelling, etc on cup and cone or rollers
 - Looseness / Fretting faults - including inner or outer ring wear, loose or spun cones, worn seals
- ◆ RailBAM® Trending Database provides automated downloading of multiple site fault data to a central Server PC at Customer Train Control



Trackside Acoustic Detection Systems are Used to Identify Defective Bearings



- ◆ Expert system interprets acoustic signatures
- ◆ Data transfer thru Internet into *InteRRIS*TM

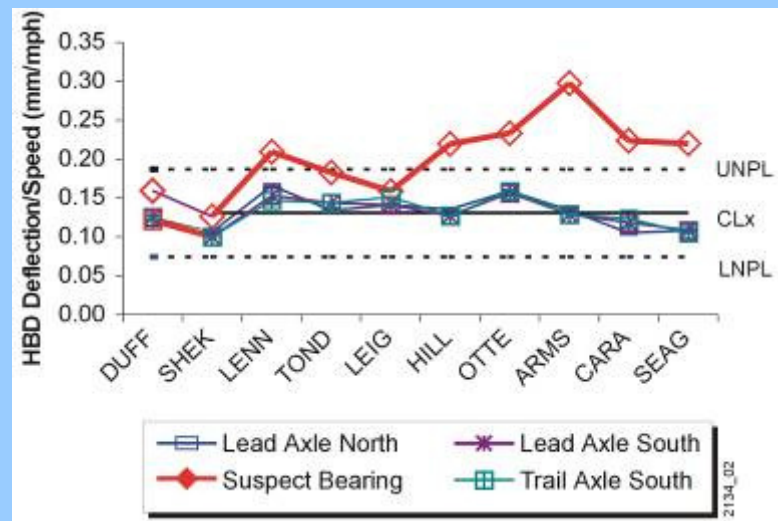


Loose cone with roller spalling, detected by large cup spall

Typical Defects Found:

- ◆ Larger cup spalls (bar lines, etc)
- ◆ Cone spalls
- ◆ Water etch
- ◆ Early spun cones (cone turning on journal, detected because of spalls)
- ◆ Roller defects (spalls and seamed)

Predictive Trends Identified from Integrated HBD System



UNPL – Upper Limit LNPL – Lower Limit



Trackside Acoustic Detection System (TADS)

- ◆ Multiple microphone trackside array
- ◆ Ethernet linked, multi-computer high-speed data acquisition system
- ◆ AEI integrated
- ◆ Internet connected
- ◆ *InteRRIS*[™] compatible
- ◆ Remote monitoring and diagnostic capability
- ◆ Lightning protected
- ◆ Notifications by e-mail, page, FAX, or modem connection





TADS Description



Trackside Microphone Array





Bungalow Equipment Enclosures





TADS Installation Experience

- ◆ 13 (soon to be 36) sites on 4 continents
- ◆ Sites cover:
 - Double & single track configurations
 - Electrified & non-electrified territory
 - North American northern climate to African/Australian southern climate conditions
 - Rural and urban locations
- ◆ Defects detected in AAR Classes “C”, “D”, “E”, “F”, “G”, and “K” roller bearings
 - Spherical roller bearings
- ◆ Over 600 bearing inspections completed to date



Representative TADS Installations



13 (soon to be 36) sites on 4 continents





Database Capabilities

- ◆ TADS data sent to single or multiple databases (e.g. customer owned and/or *InteRRIS*[™])
- ◆ Evaluation results sent on each bearing of each train – defect present (Y or N)
 - 2 outputs for suspected defects
 - ▼ Defect location, severity ranking
- ◆ Database tools available for:
 - Graphical display of train, car, or bearing history
 - Acoustic review of detected bearing defects





Wayside Inspection Devices – T/BOGI



- ◆ **Truck/Bogie Optical Geometry Inspection (T/BOGI) station is a powerful new tool enabling railroads to reduce their operating costs by monitoring bogies for correct alignment**
- ◆ **Measures the angle of attack and tracking position of individual wheelsets of a passing train in real time.**



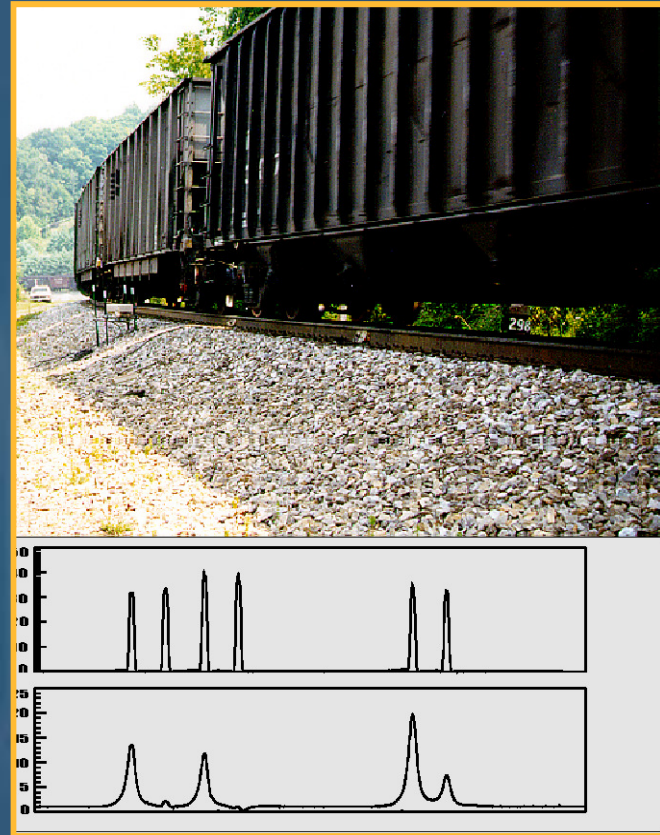
Truck Performance Detector (TPD) Primary Measurements

- *Lateral Wheel Load*
- *Vertical Wheel Load*
- *Axle Angle of Attack (AoA)*
- *Automated Equipment Identification (AEI)*



TTCI Truck Performance Detectors Identify Poorly Performing Trucks

- ◆ **Flange Climb** *High L/V and AoA*
- ◆ **Rail Roll Over** *High TSLV*
- ◆ **Track Panel Shift** *High NAL*
- ◆ **Gage Spreading** *High Lateral*
- ◆ **Warped Truck** *High AoA*
- ◆ **Wheel Unloading** *Low Vertical*
- ◆ **Track Damage** *High Vertical*



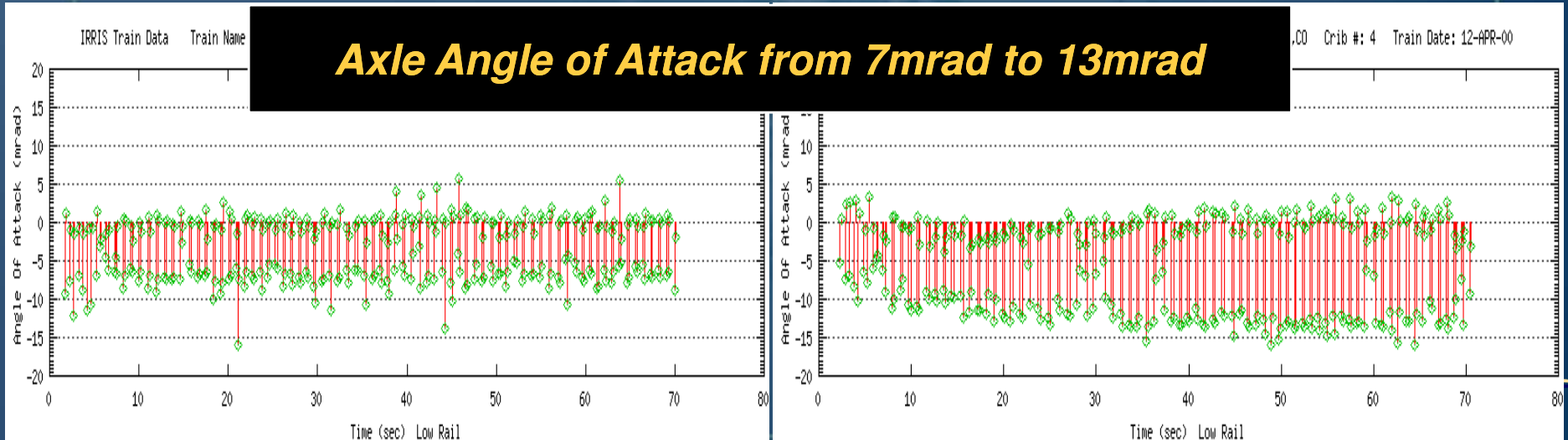
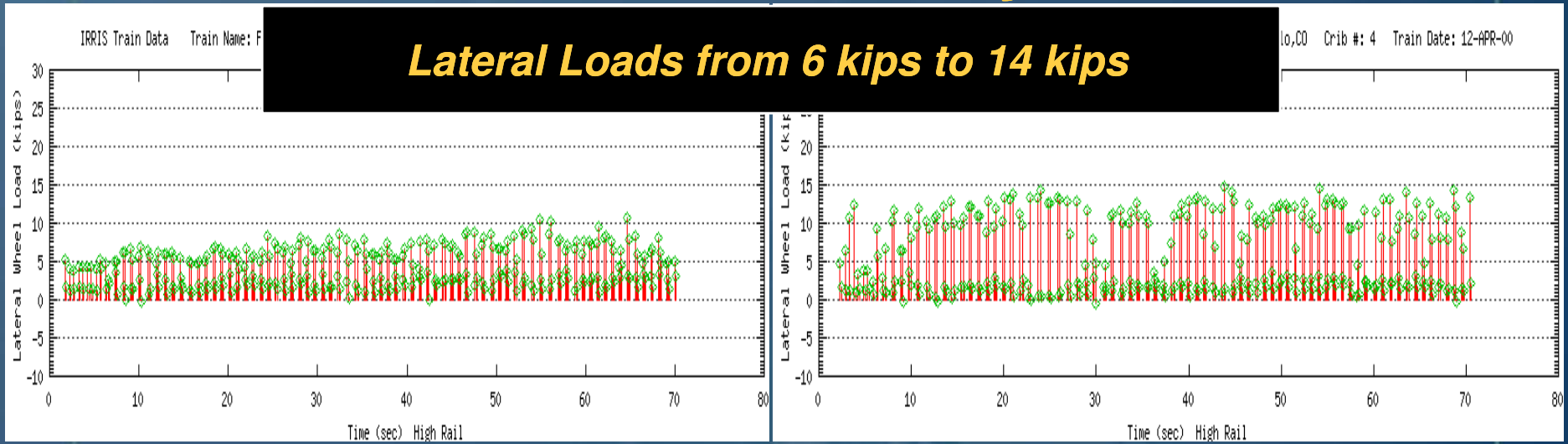
- ◆ **Increase Safety**
- ◆ **Reduce Fuel Costs**
- ◆ **Evaluate New Components**
- ◆ **Optimize/Schedule Vehicle Repair**
- ◆ **Reduce Damage to Track & Equipment**

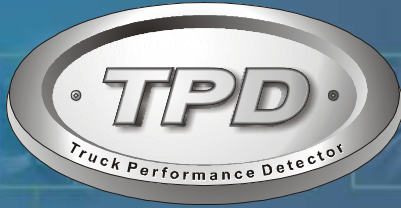


High Rail Time Plot from FAST Train

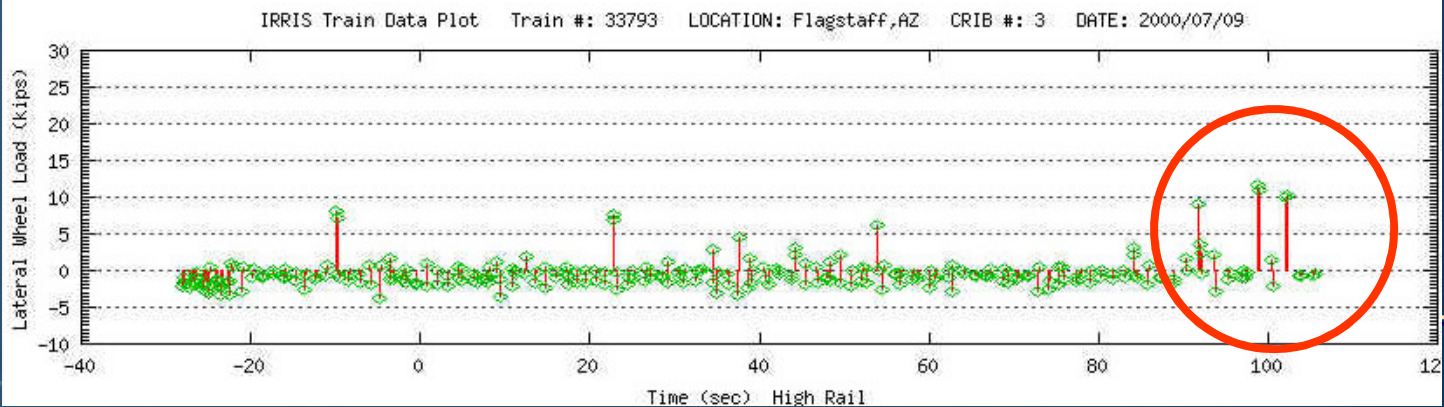
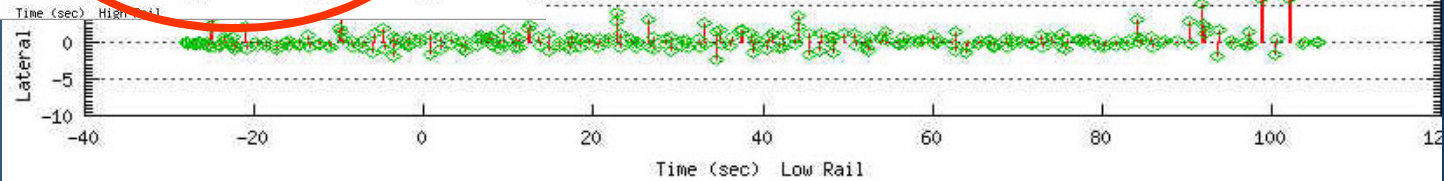
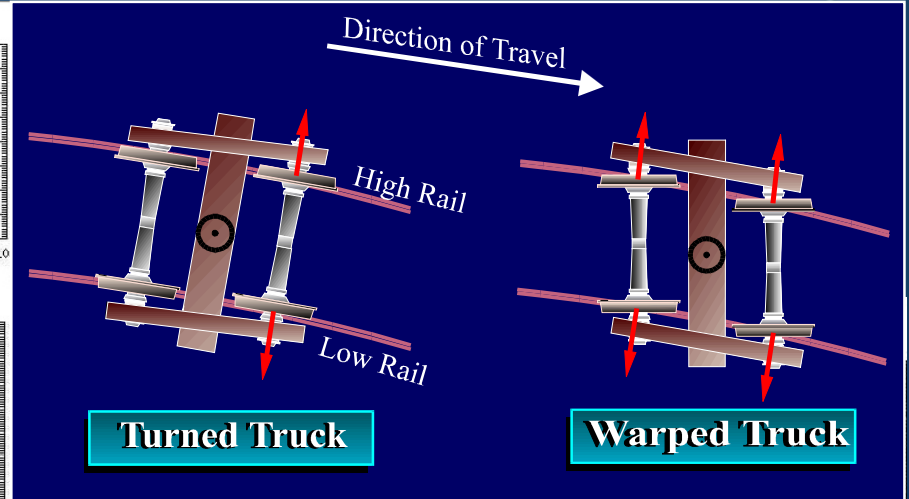
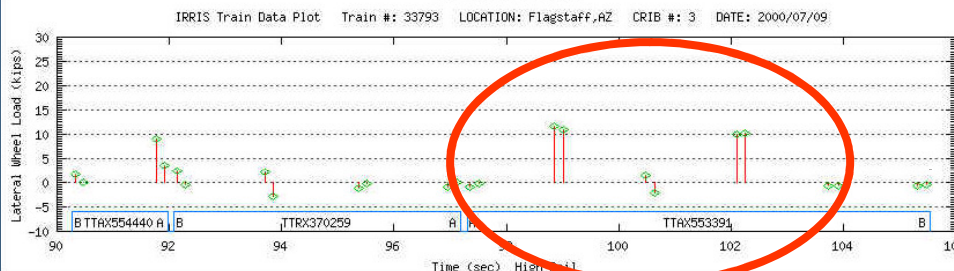
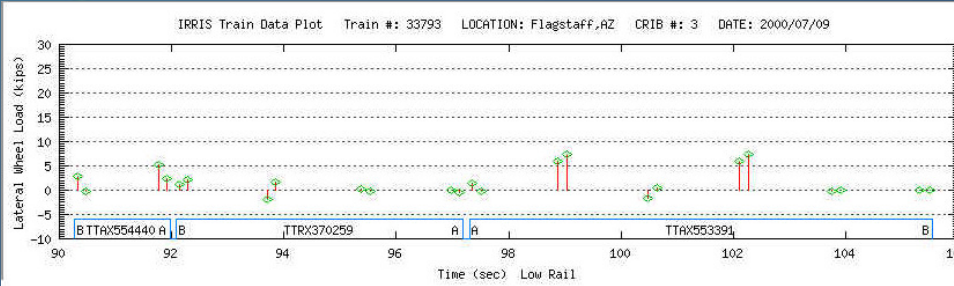
Ideal Lube Condition

Dry Lube Condition





Tangent Lateral Forces of a Vehicle that Derailed



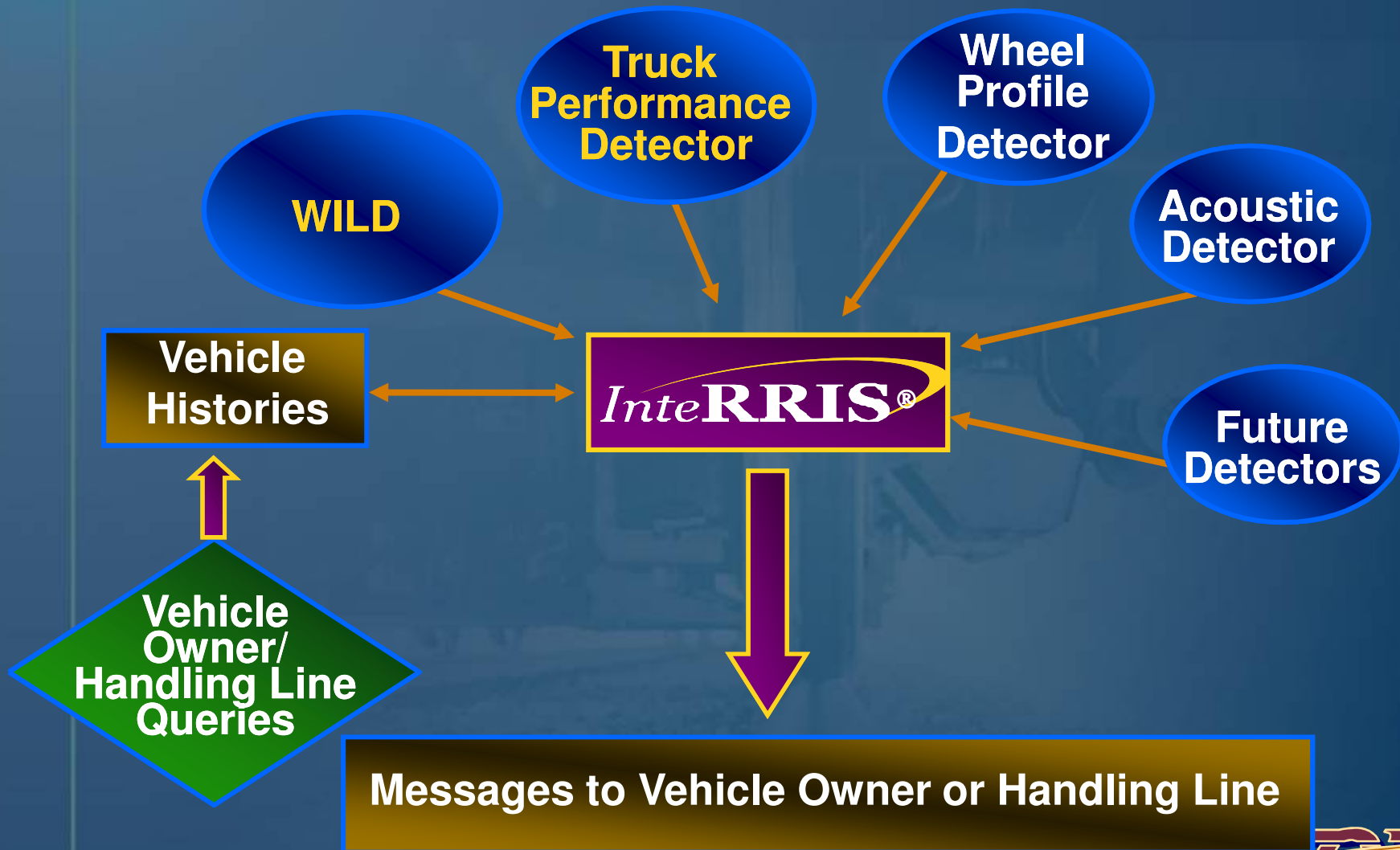


What is InteRRIS[®] ?

- ◆ **Integrated Railway Remote Information Service**
- ◆ **Database for automatically storing and analyzing vehicle performance data**
- ◆ **TTCI began development in 1999**
- ◆ **Specific notifications are sent to its customers about vehicle performance based on their unique parameters, criteria, and limits**



New and Existing Detectors





TTCI Vehicle Health Monitoring Objectives

- ◆ **Develop wayside vehicle health monitoring systems**
 - Monitor passing trains with wayside inspection systems
 - Measure vehicle performance characteristics that can contribute to excessive stresses
 - Identify specific vehicles with inspected parameters that exceed stress thresholds
 - Report identified vehicles to appropriate railroad maintenance organizations

- ◆ **TTCI research focused on three wayside systems in 2004**
 - Cracked wheel detection – SRI 6A
 - Cracked axle detection – eight member consortia
 - Automated car inspection – TTCI IR&D / partnership





Wayside Cracked Wheel Detection

Chronology of Development Efforts

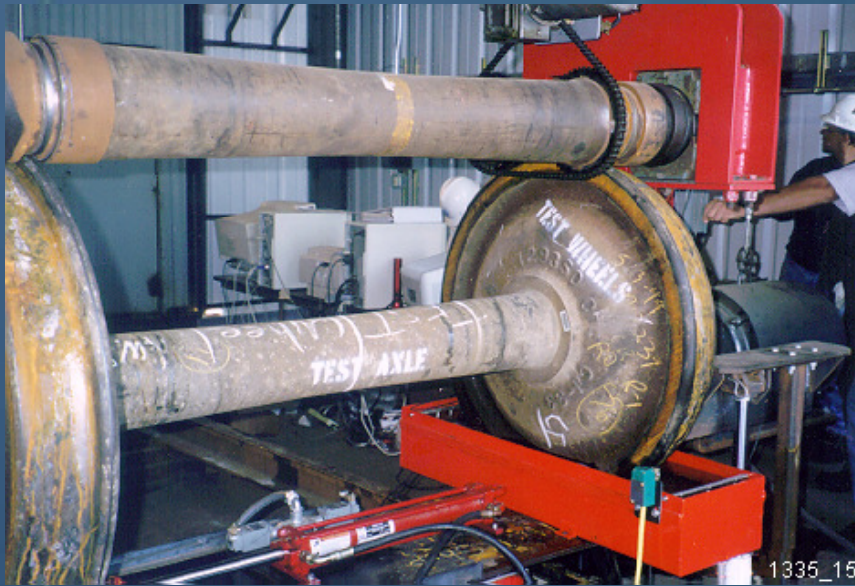
- ◆ **2000:** Ultrasonic NDI testing at Hollidaysburg
- ◆ **2001:** Feasibility experiment with Center for Non-Destructive Evaluation (CNDE) at Johns Hopkins University (JHU) using Laser Ultrasonic NDI technology
- ◆ **2002:** Development / conduct of a Proof of Concept (POC) demonstration at TTCI using Laser technology
- ◆ **2003/4:** Additional research at JHU and development & testing of a CWD limited prototype system at TTCI using Laser Ultrasonic technology





Wayside Wheel Crack Detection

Hollidaysburg Summary



In-shop Rotating Wheel Detection System

- UT applicable for wheel in-shop inspections
- Issues for wayside application:
 - System reliability
 - Detection of critical defects
 - Adequate ultrasonic coupling
 - System maintenance requirements
 - System complexity



Wayside Wheel Crack Detection



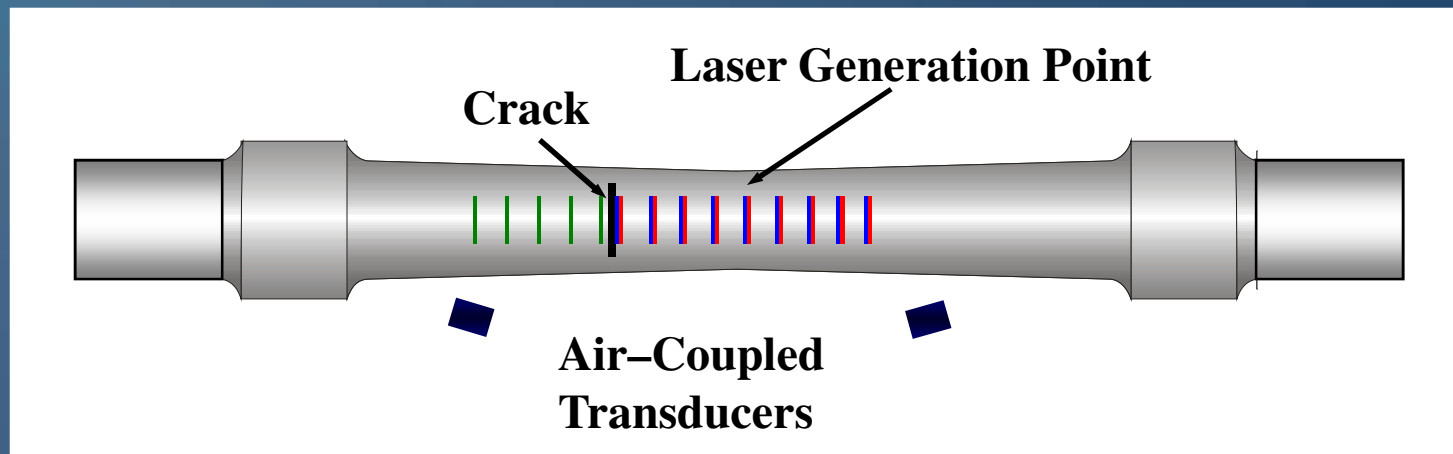
Contract with CNDE at JHU

Objective: Develop a wayside ultrasonic nondestructive inspection (NDI) capability for railway wheels in motion

- **NDI wheel inspection capability requirements :**
 - **Inspect moving wheels on track**
 - **Inspection sensors work without contacting wheels**
 - **Components robust for RR operational environment**
 - **Rapid inspection methods to meet motion requirement**
- **NDI capability implemented in three phases**
 - **Phase 1 – Laboratory tests to demonstrate feasibility**
 - **Phase 2 – “On-track” proof-of-concept demonstration**
 - **Phase 3 – Operational prototype system at TTC**



Axle Inspections Using Laser Ultrasonics



- ◆ Focusing laser to a line generates surface waves
- ◆ Surface waves propagate in both directions (red lines)
- ◆ Both transducers receive peak amplitude direct surface waves when no crack is present
- ◆ If a crack is present
 - Peak amplitude direct waves received by one transducer
 - Waves transmit through the crack (green lines)
 - Waves reflect off of the crack (blue lines)

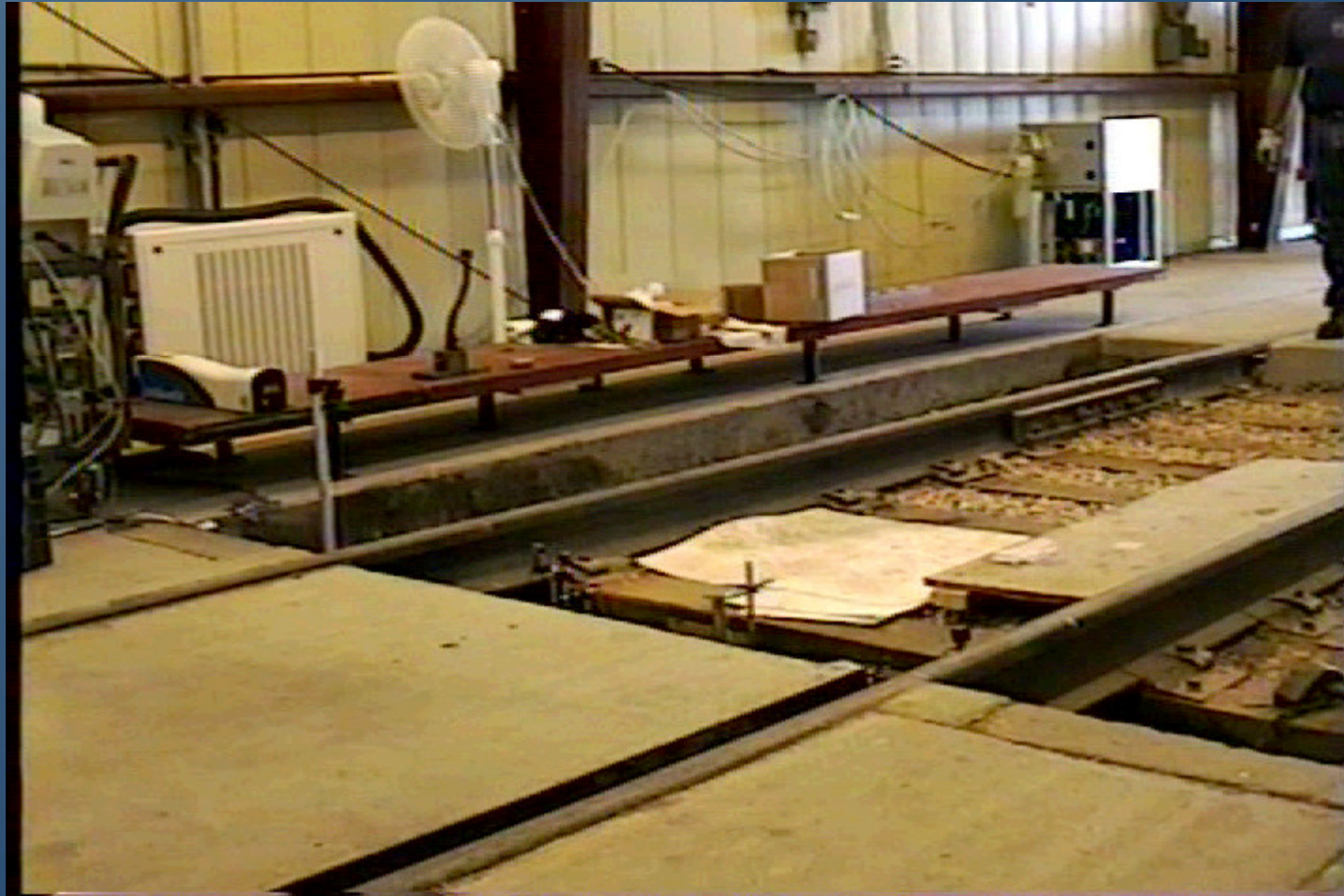
Proof of Concept (POC) Demo



- ◆ Most equipment placed alongside track
- ◆ Mirrors directed laser beam under the track, then to the axle
- ◆ All equipment in crib located at least 2 in. below top of rail
- ◆ Laser pulsed at the center of axle body
- ◆ Transducer to axle body air gap varied from 6 inch to 16 inch
- ◆ Test axles
 - Two axles with no defects
 - Axle 89 $\geq 1\frac{3}{4}$ -inch crack
 - Axle 125 $\geq 1\frac{1}{4}$ -inch crack



POC Demonstration Video



POC Demo Results & Prototype Status

Crack #	Crack Type	Crack Size	Total Passes	Total Cracks	Cracks Detected	Detection Rate
1	A	2 in	47	47	44	94%
2	A	2 in	40	40	38	95%
3	A	2 in	40	40	29	73%
5	S	1.75 in	60	60	50	83%
6	S	1.25 in	19	19	19	100%
no	no crack	n/a	41	0	1	n/a

- ◆ 87.86% cracks correctly identified
- ◆ One false positive in 41 total passes
- ◆ Cracks near wheel seat produced less favorable results
- ◆ Improving set-up conditions will improve results

- ◆ Initial limited prototype in development & will be installed at TTCI





The Future

- ◆ **Integrated network of wayside inspection stations**
 - Quantitative data on components of individual vehicles
 - Data trending analyses → predictive maintenance strategies
- ◆ **Systems of multi-sensor technologies**
 - HSVI + IR for 1000 mile brake inspections
 - HSVI + 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



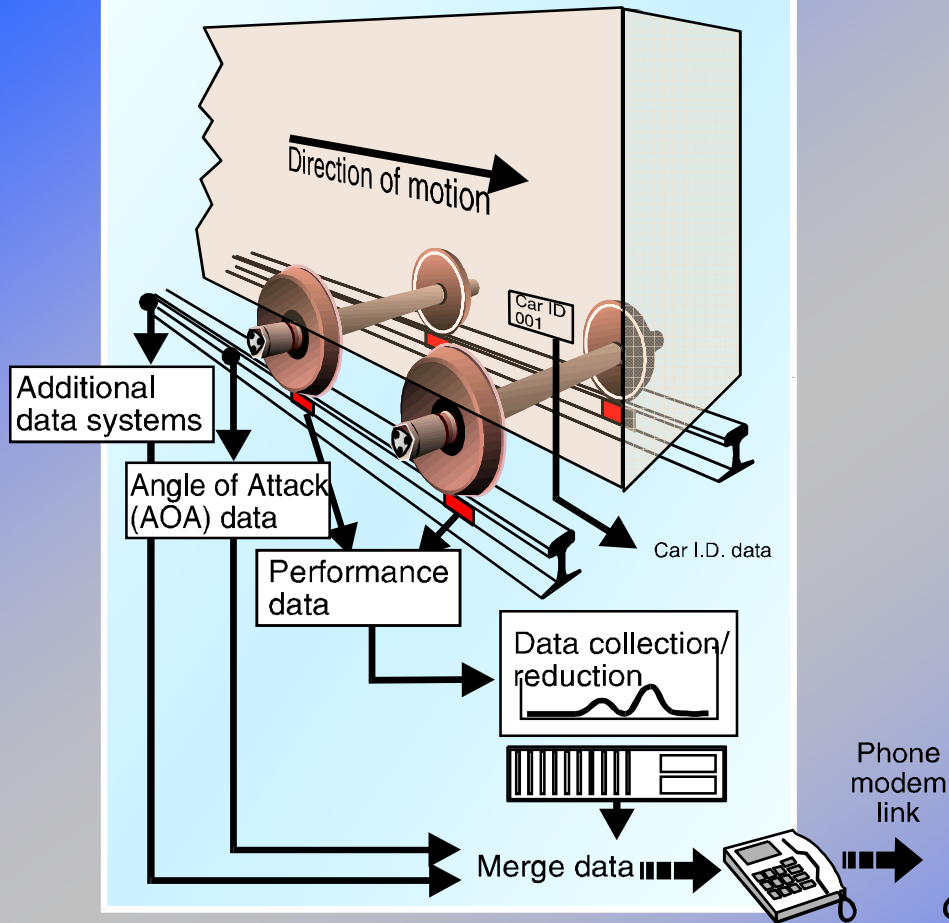


Technology Driven Train Inspection (TDTI)

Backup Slides

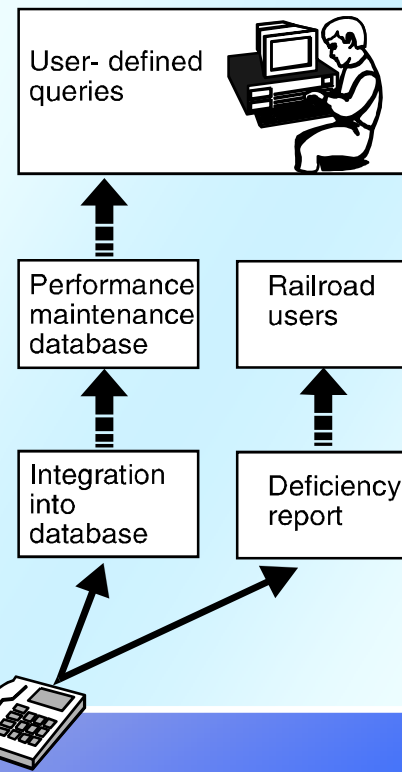
Truck Performance Detection (TPD)

Remote Test Location



Wayside Detection

Distant Site



00190fil13_ways cdr

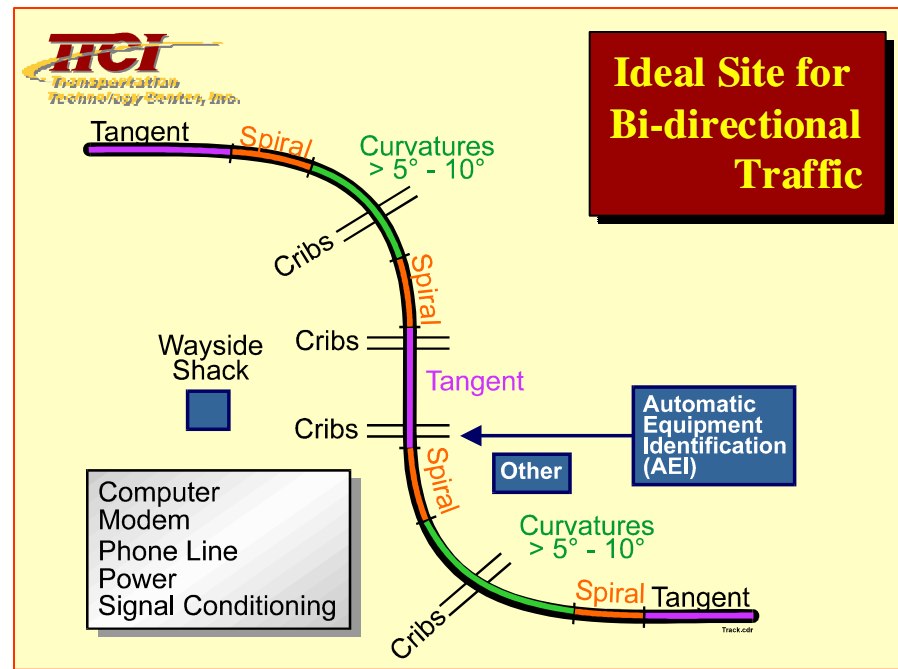
TM

Gage Layout Meets

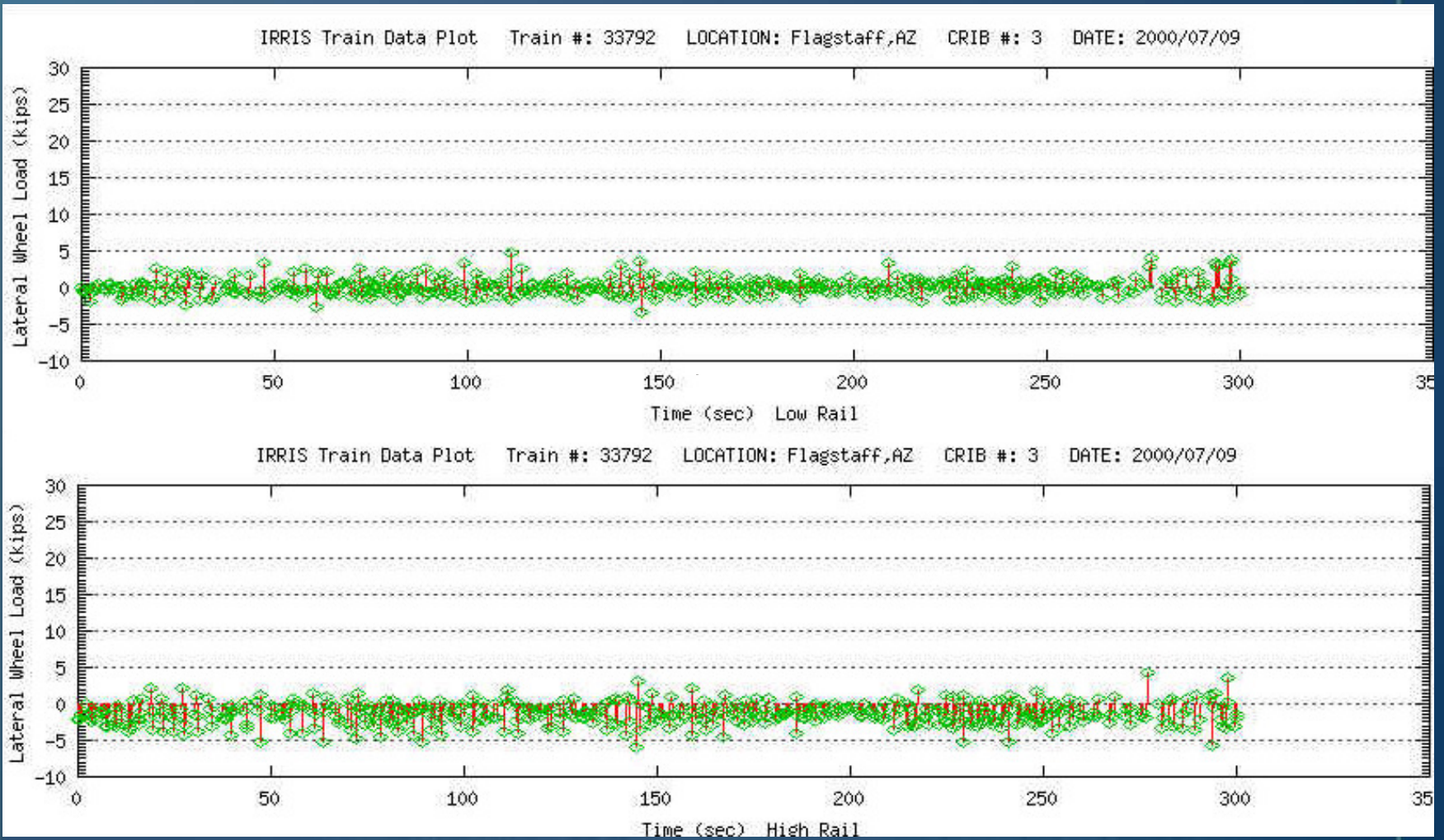
T_ruck P_erformance R_esearch C_onsortium Requirements

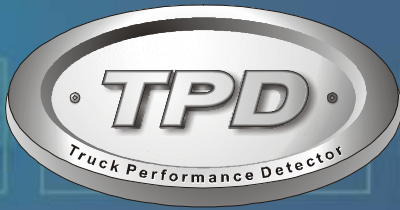


- More accurate measurements in BOC
- Redundant gages
- More accuracy when needed with position gages



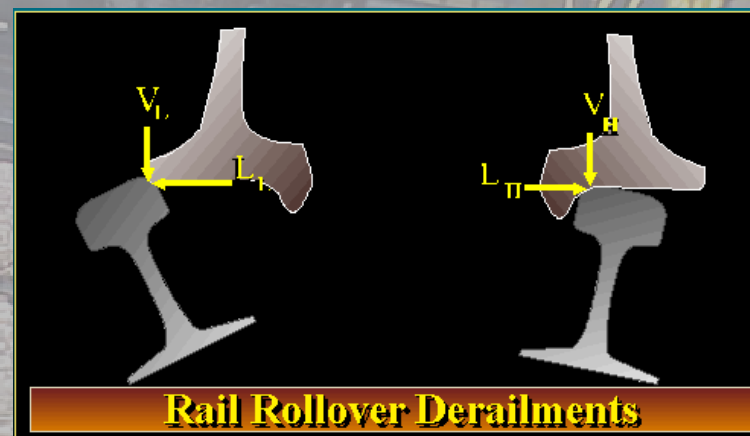
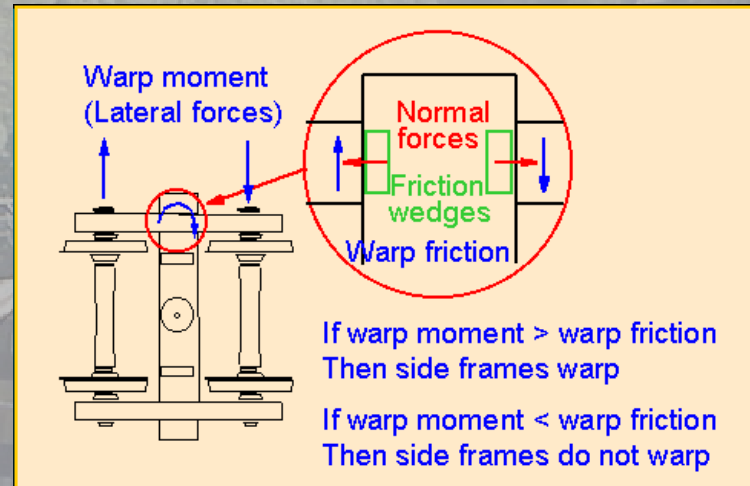
Typical Lateral Forces in Tangent

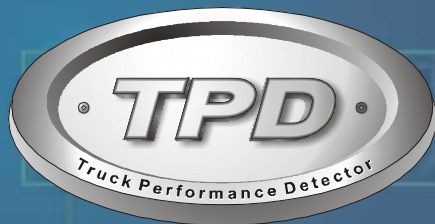




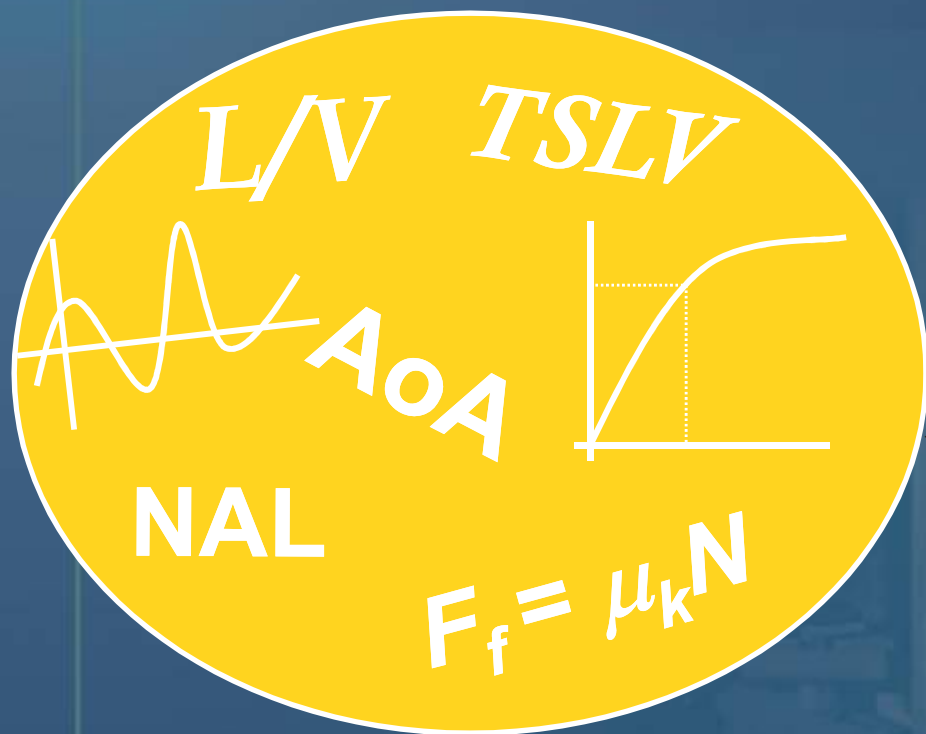
Vehicle Performance Evaluations

- ◆ **Flange Climb**
High L/V and AoA
- ◆ **Rail Roll Over**
High TSLV
- ◆ **Track Panel Shift**
High NAL
- ◆ **Gage Spreading**
High Lateral
- ◆ **Warped Truck**
High AoA
- ◆ **Wheel Unloading**
Low Vertical
- ◆ **Track Damage**
High Vertical

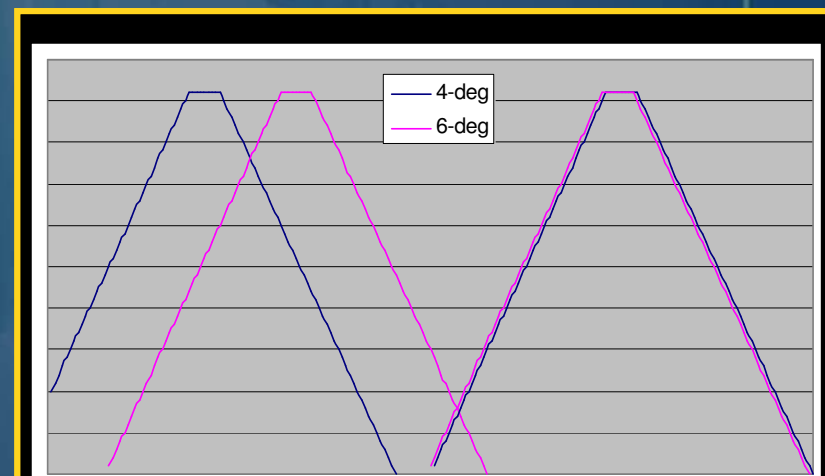




One Number Criteria for A More Comprehensive and Simplified Bad Actor Evaluation

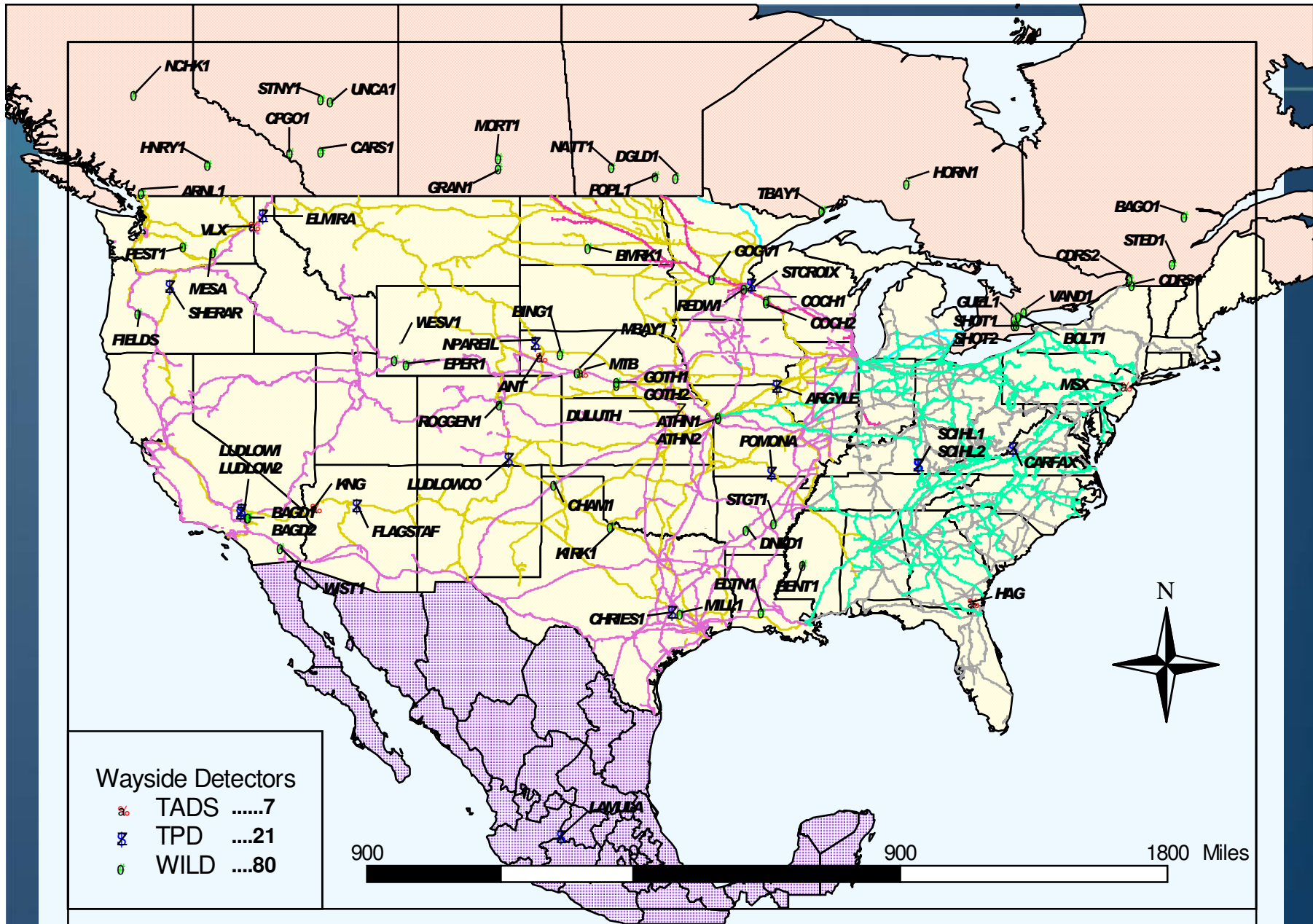


85



Plus Curvature Compensation

**TPD Evaluates Parameters and
Reports on a Scale of 0 to 100**



Wayside Detector Distribution Contributing to InteRRIS(tm)

Detector sites as of 11/11/2003.

Based on USGS DLG. 1:24,500,000, Geographic Projection, DD.
2003 (c) , Transportation Technology Center, Inc.



The Big Picture

Wayside SITES



- Process Raw Data into Peak Files
- Process AEI Car ID Files
- Transmit Peak/AEI Files
- Real-Time Events

InteRRIS® Data Staging Server

Database SERVER



- Store Site/ Train/ Vehicle Data
- Maintain Integrity Constraints

THE NET

InteRRIS® WEBSERVER



- Service Client DB Requests
- Maintain Secured Internet Access

- Receive Detector Data Files
- Perform Criteria Checks
- Notify Customer of Events
- Auto-Load into Data Warehouse

Customer SERVICE

WWW THE NET



- Inbound Action Items
- Event Notification
- Periodic Reports
- On-Line Access for Further Analysis

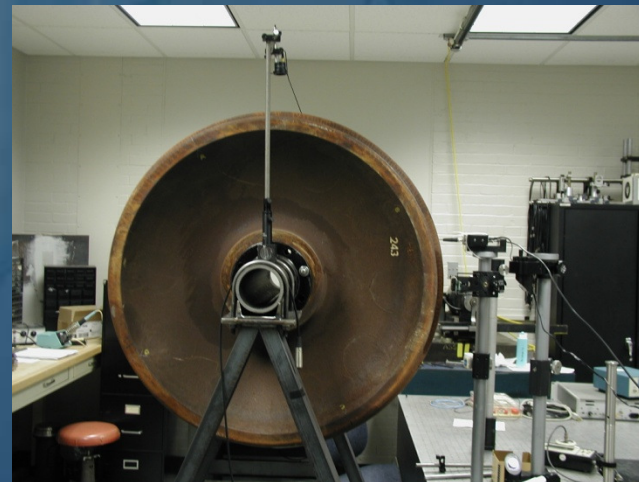
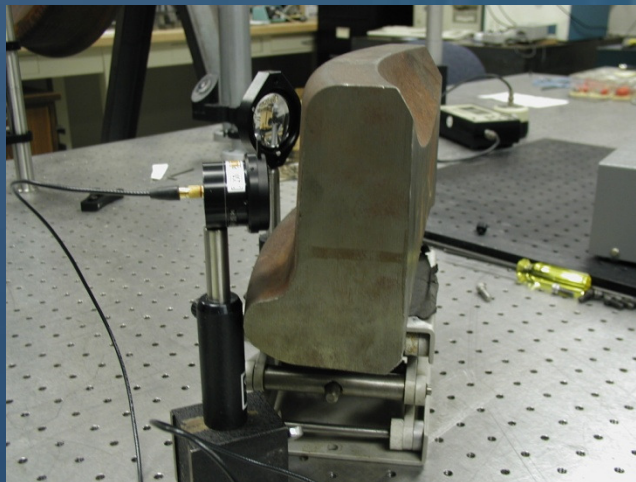
Wayside Wheel Crack Detection



Phase I - Feasibility Experiments at JHU

◆ Phase I activities:

- Evaluated a variety of ultrasonic test methods
- Performed assessments of potential test configurations
- Developed test concepts to cover large wheel areas at greatly reduced sample rates
- Tested ultrasonic signals on actual wheel samples
- Selected remote ultrasonic technology based on laser to air coupled transduction

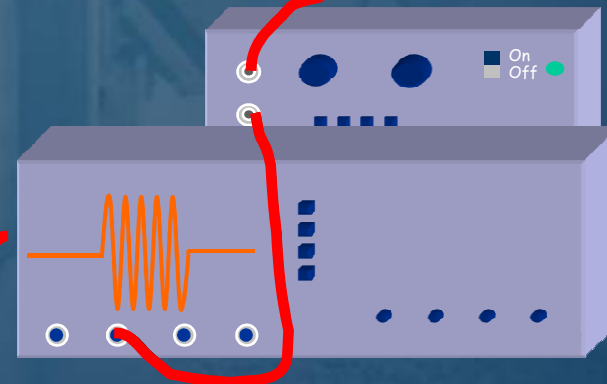
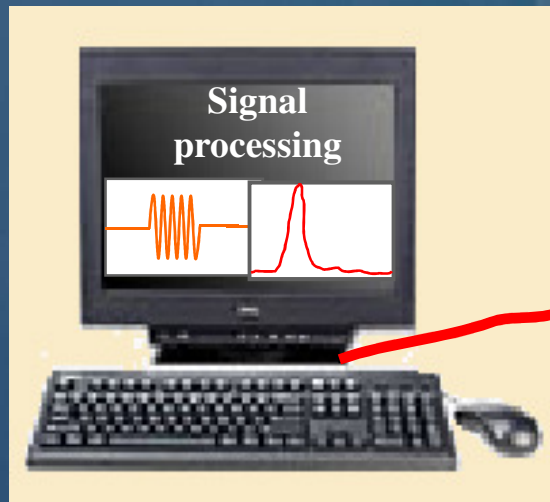
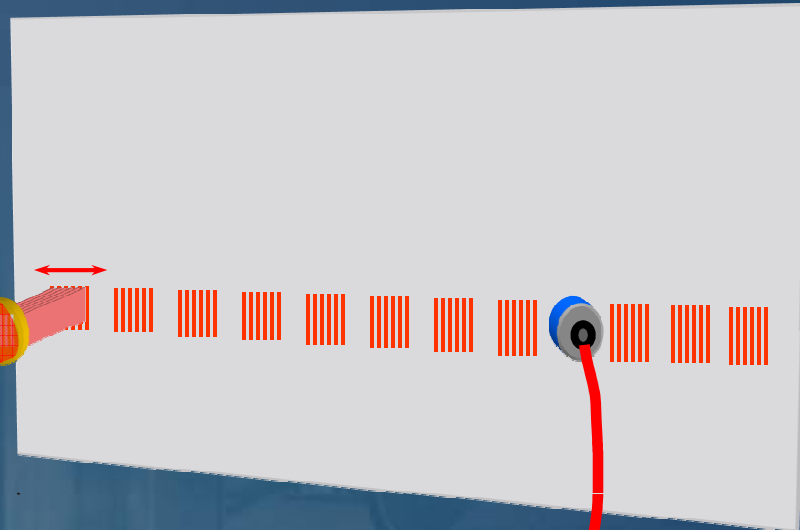
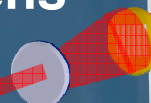
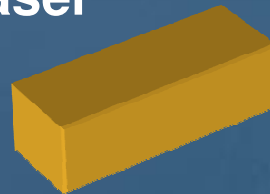


Laser Ultrasonic – Experimental Set-Up

Laser Ultrasonic Remote Inspection System

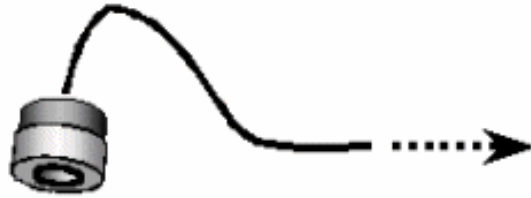
ND:YAG
Laser

Lens

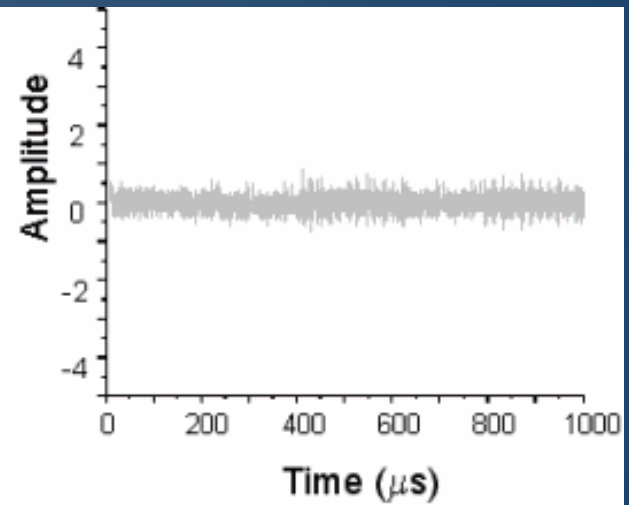
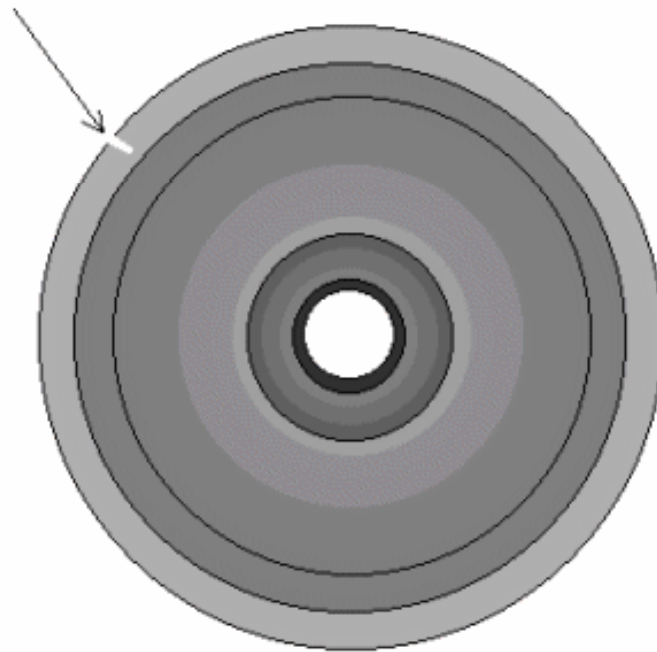


Cracked Wheel Detection – Flange Crack

Capacitive
Air-Coupled
Transducer



Crack



Lens
Assembly

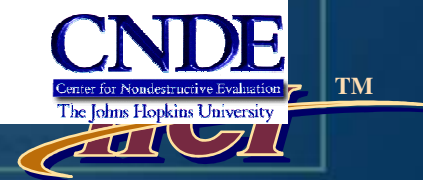
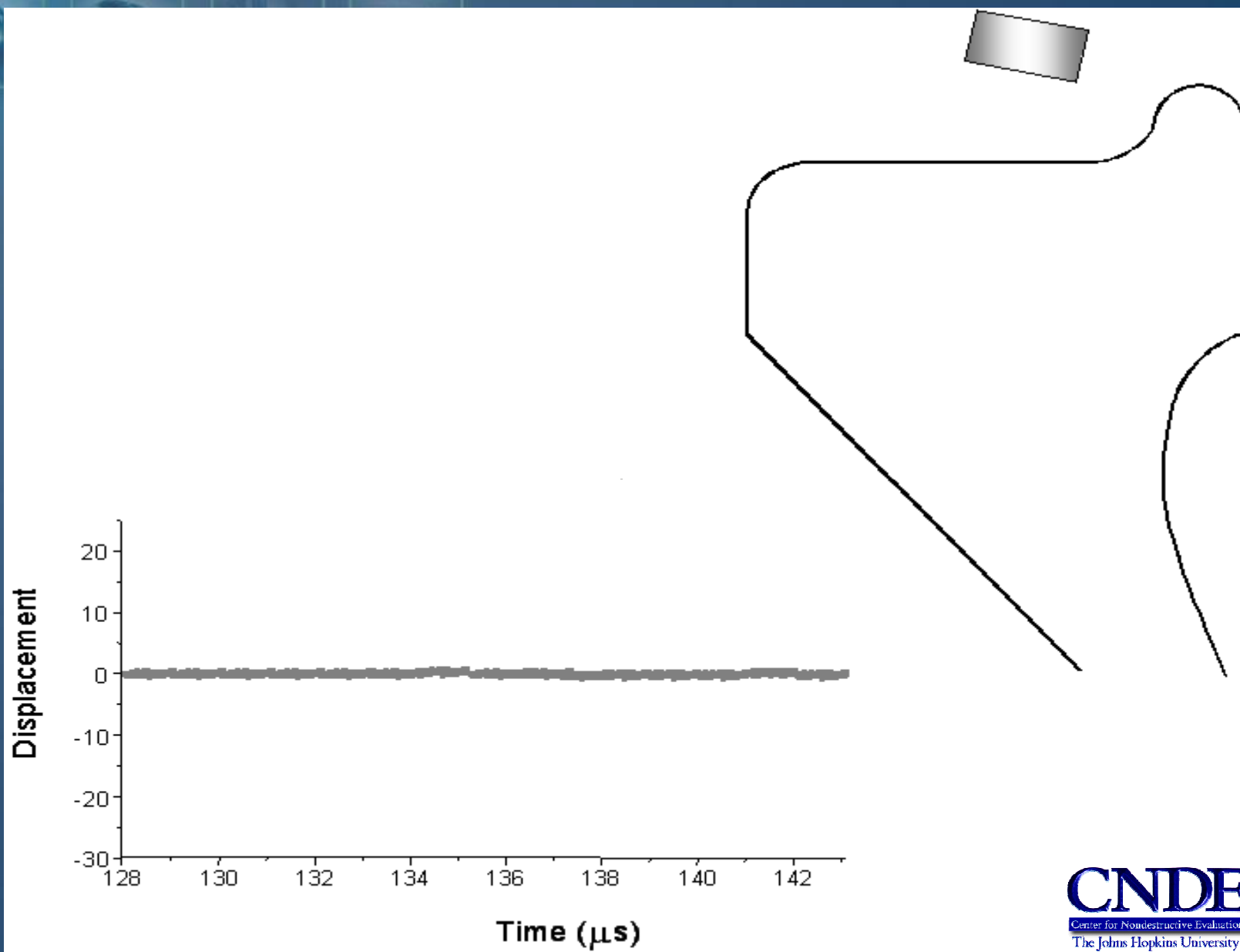


IR Pulse
Laser

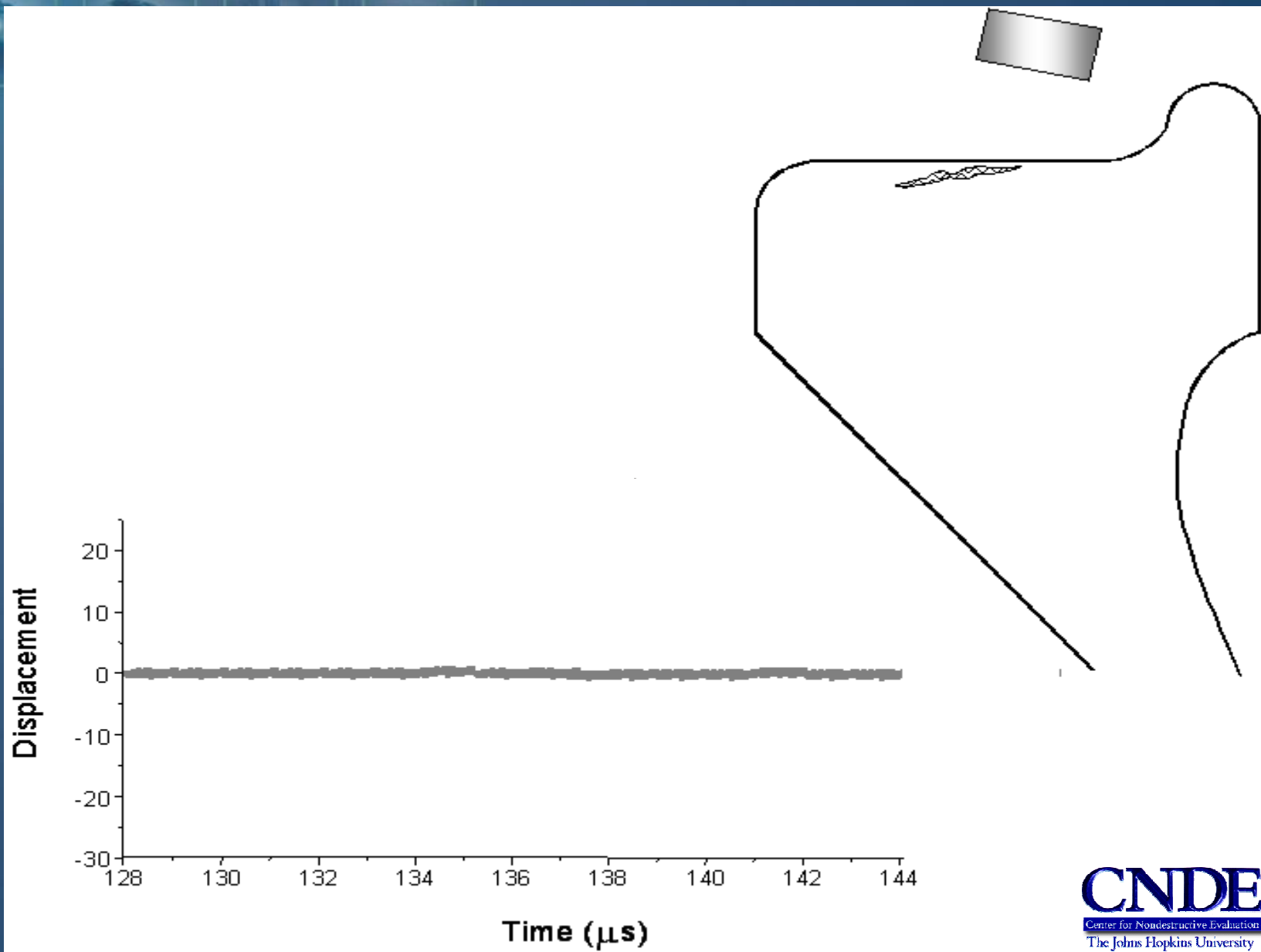
CNDE
Center for Nondestructive Evaluation
The Johns Hopkins University



Cracked Wheel Detection – No Defects



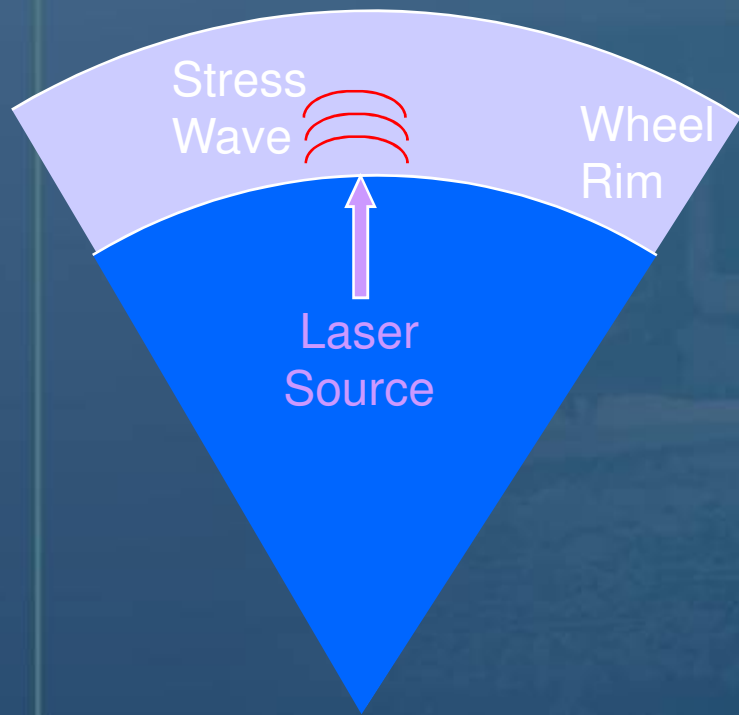
Cracked Wheel Detection – Shattered Rim Crack



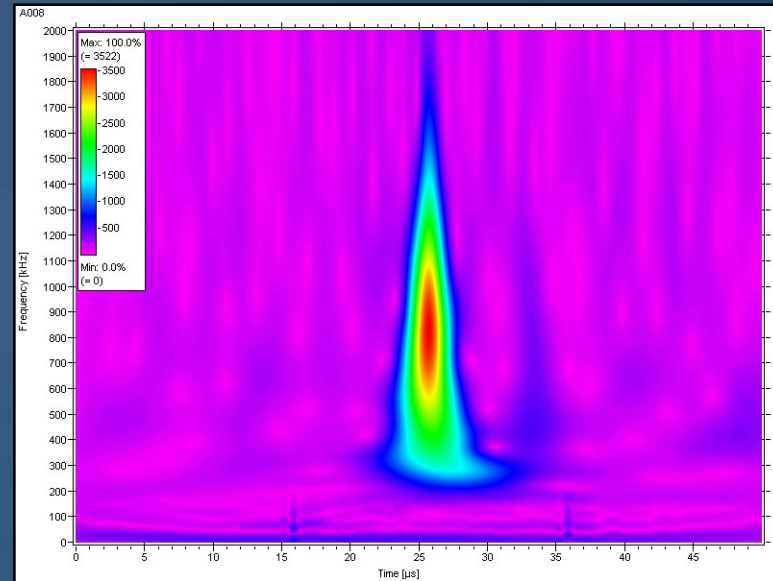


No Crack

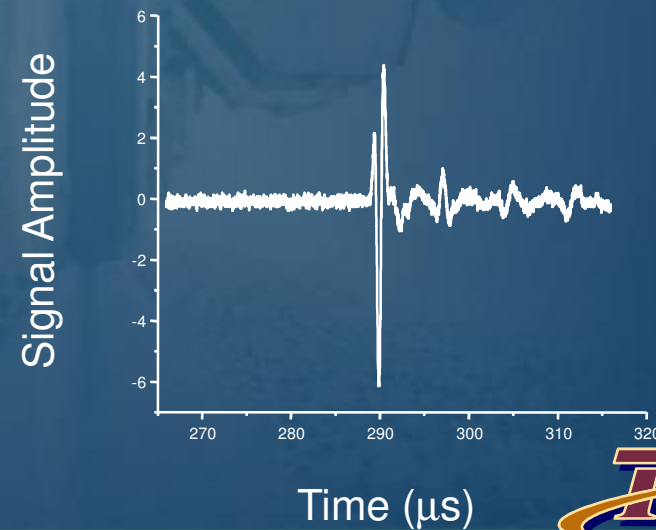
Air-Coupled
Detector



Frequency



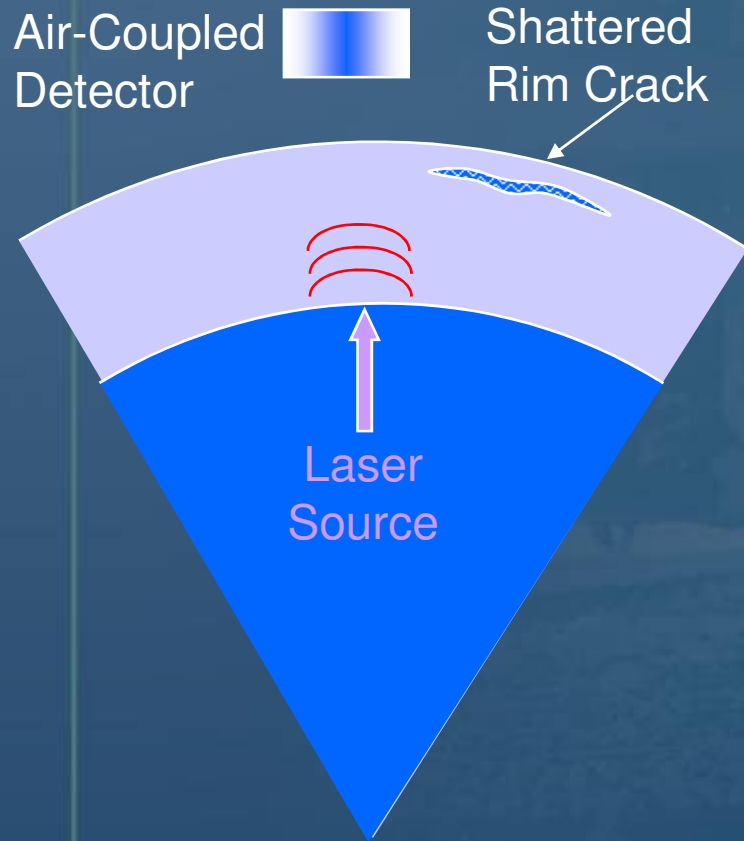
Time Of Flight



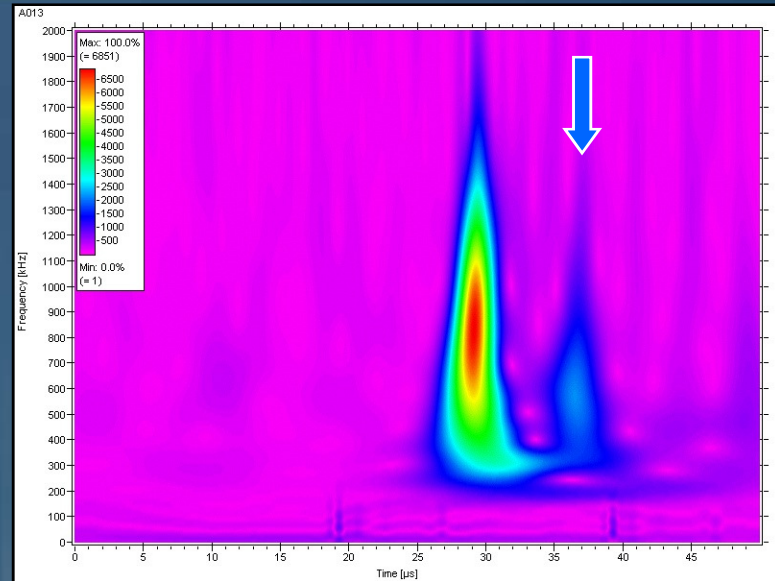


Near Crack Edge

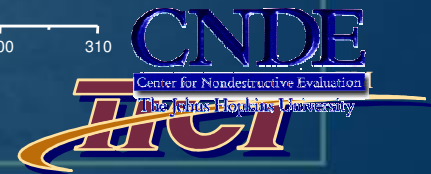
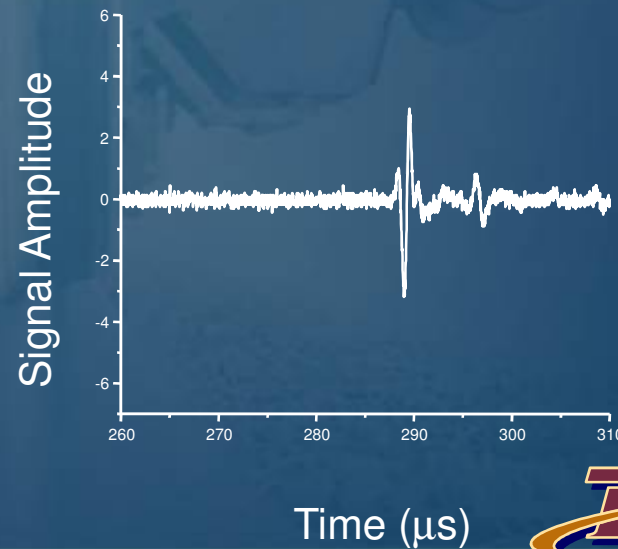
10 mm from Edge



Frequency

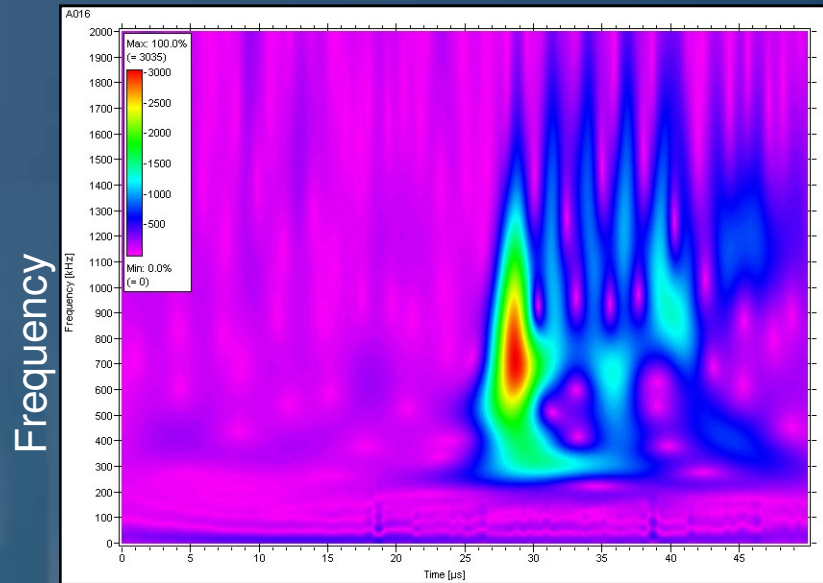
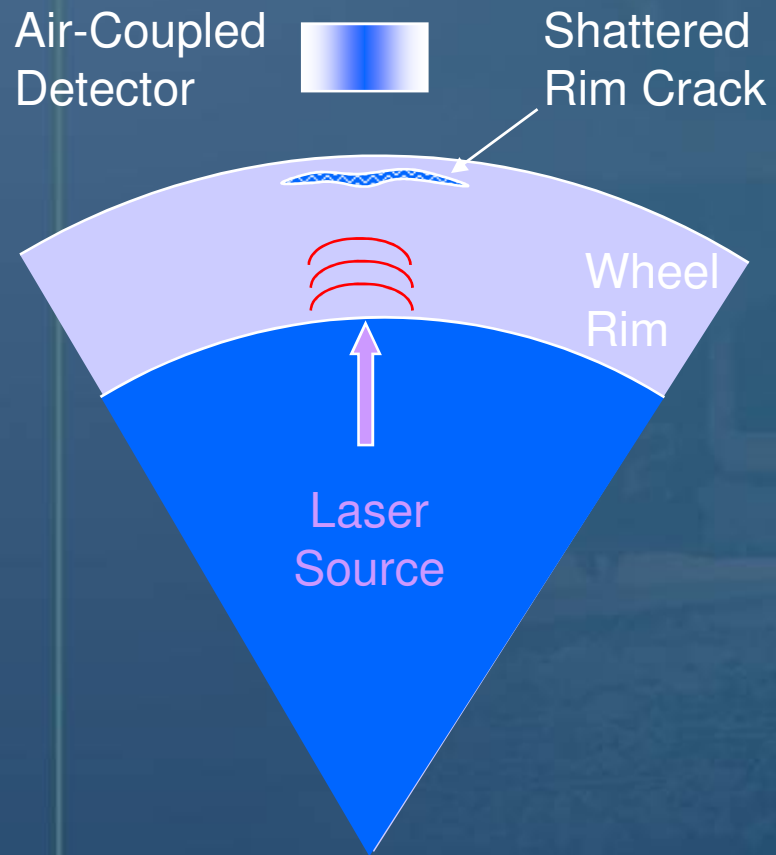


Time Of Flight

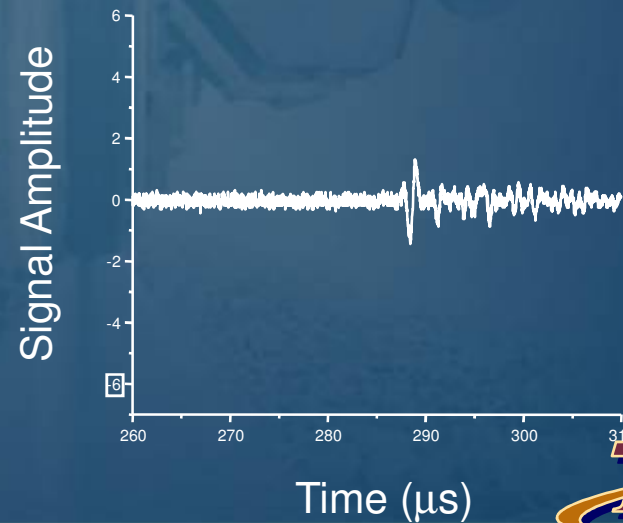




On Crack



Time Of Flight





Cracked Wheel Detection

CWD Phase II – POC Demo

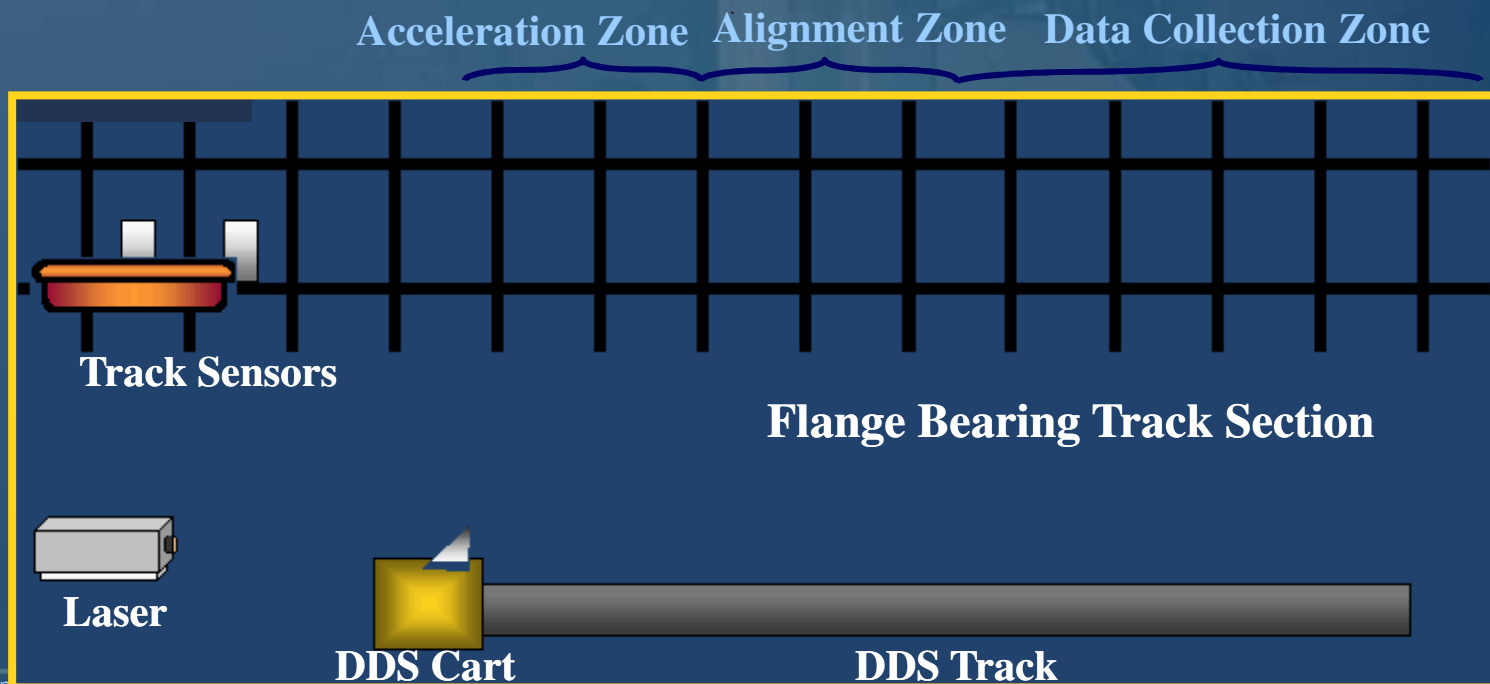
- ◆ **Proof of Concept (POC) Demonstration**
 - 10 characterized wheel sets used for testing
 - Wheels tested for flange and tread fatigue cracks and Shattered Rim Cracks(SRC's)

- ◆ **POC Results**
 - 100% of flange tip cracks detected
 - 100% of tread cracks detected (w/ wet surface)
 - 92% overall success rate for SRC



CWD Phase III – Limited Prototype

- ◆ Focusing laser to a point, generates bulk waves
- ◆ Bulk waves, shear and longitudinal, travel through the rim
- ◆ Transducer receives clean signals when no crack is present
- ◆ With crack present:
 - Bulk waves are attenuated
 - Supplementary waves produced by crack
 - Additional frequency content with crack present





Consist Test

- ◆ **Test consist included five cars**
 - Lead axle was used for placement of test wheels
 - Five non-defective and five defective wheels used
 - Defective wheels were characterized using NDT techniques before placed on consist
 - Test runs were conducted at 5 mph in a single direction





Consist Test Video



No Picture



Test Results

- ◆ **Static and dynamic data from inside track tests showed prototype's ability to detect cracks in wheels**
- ◆ **Good results from some, but not all, consist test runs**
 - **Areas of improvement:**
 - ▼ **Repeatability**
 - ▼ **Stability**
 - ▼ **Component durability**
- ◆ **Initial production system in work with a commercial development partner**





Initial Laboratory Research

- ◆ **Determine the feasibility of detecting surface breaking cracks in an axle body and wheel seat**
- ◆ **Study the effects of variation of:**
 - Length of laser source with respect to the amount of coverage area
 - Distance between laser impact point and transducer receiving position
 - Distance between laser impact point and crack position
 - Orientation of transducers with respect to the laser impact point
 - Simulated loading condition on wheel seat
- ◆ **Laboratory research showed that laser-based ultrasonic inspection is capable of detecting cracks in the axle body and wheel seat**

