BNSF is a Leading U.S. Railroad

- A Berkshire Hathaway company
- **41,000** employees*
- Approximately **8,000** locomotives
- Moves **one-fourth** of the nation’s rail freight
- Operates over **1,200** freight trains per day
- A leader in the industry in **technological innovation**

*BNSF Railway employees as of Dec. 31, 2016
BNSF is a Leading U.S. Railroad

- **32,500 route miles** in 28 states and three Canadian provinces
- **13,000 bridges and 88 tunnels**
- Serves **over 40 ports**
• **First ever** to be focused on the advancements and applications of the ever increasing array of new technologies to improve railway safety, operations, and efficiency.

• Bring together the railroad and rail transit community to exchange information and advance the state of the art with objectives of:
  
  • Improving the effectiveness of existing technologies
  
  • Development and **implementation** of new technologies
  
  • Research on emerging technologies with the potential to improve rail transport
  
  • Goal of connecting industry needs with the people and organizations that can develop solutions

  “**Discuss yours and BNSF’s perspective, vision, and leadership regarding inspections technologies and their vital importance to the future of rail safety, efficiency, and reliability.**”
Since 2007, the industry rail equipment incident rate has been reduced by 32% and BNSF’s rail equipment incident rate has been reduced by 42%.

Source: FRA 1.12 – Ten Year Accident/Incident Overview. Excludes Highway Crossing Accidents.
On BNSF All Types of Incidents Have Declined

Source: FRA 1.12 – Ten Year Accident/Incident Overview. Excludes Highway Crossing Accidents.
Prevention: Reducing Risk

Human Factor
- Training
- Remote monitoring
- Positive Train Control
- Self reporting protocol

Equipment/Mechanical
- Ultrasonic inspection
- Detector network - dragging equipment
- Technology
  - Thermal/infrared scanning for warm bearing detection

Track/Signal
- Enhanced track inspection training
- Continued elimination of jointed rail & joints in CWR
- Strong capital program in rail, tie, and ballast renewal
- Technology - enhanced geometry testing, aggressive rail detection program, improved use of data

Our ongoing focus is on instilling a culture of commitment and compliance – a culture that is sensitive to exposure and risk.
Inspection Capabilities and Methods

MECHANICAL

Railcar – Equipment Detection

Locomotive – RM&D

ENGINEERING

Track Inspection

Structures Inspection

Real-time monitoring of locomotive health & performance
Data transmission to monitoring & diagnostic center
Root cause analysis & repair recommendations
Prevention: Equipment Detection Technology

- More than 2,000 trackside detectors
- Hot Box Detector (HBD)
- Wheel Load Impact Detector (WILD)
- Trackside Acoustical Detector (TADS)
- Sonic Cracked Wheel/Axle Detector (CWAD)
- Machine Vision Systems
- Magnetic Particle Inspection
- Warm Bearing Detection System (WBDS)
- Hot Wheel Detectors (HWD)
- Truck Performance Detectors (TPD)
Technology driven risk reduction – 2001 – 2016 Mechanical Derailments

Mechanical Derailment Frequency by Year per Million Train Miles

Technology / Processes

1. WILD and TPD Initial Installations
2. Warm Bearing Analysis and Acoustic Bearing Detectors
3. WILD increased coverage and process improvements
4. Cars Out of Storage Process
5. Machine Vision – Coupler Carrier/ Cross Key
6. Comprehensive Mechanical Equipment Health (CMEH)

Mechanical (‘01–’16)

- Bearing related: HWD, HBD, ABD -11%
- Wheel related: WILD -2%
- Truck related: TPD -5%

All Mechanical Derailment CAGR -6.33%
Service Interruptions (2010 – Present)

Service Interruptions (SI) by Category

<table>
<thead>
<tr>
<th>Primary Cause</th>
<th>Count of SI's (Thousands)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air hose</td>
<td>5</td>
</tr>
<tr>
<td>Brakes</td>
<td>2</td>
</tr>
<tr>
<td>Knuckle</td>
<td>2</td>
</tr>
<tr>
<td>Bearing</td>
<td>1</td>
</tr>
<tr>
<td>UDE</td>
<td>1</td>
</tr>
<tr>
<td>Car body</td>
<td>1</td>
</tr>
<tr>
<td>Wheel defect</td>
<td>0</td>
</tr>
</tbody>
</table>
Detector Network Overview

Failure modes driving continued development
## Detector Network Overview

### Bearing Monitoring

<table>
<thead>
<tr>
<th>Technology</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acoustic Bearing Detector (ABD)</td>
<td>Identifies defects on specific internal bearing components (e.g. cup, cone, roller and cage) based on acoustic signature.</td>
</tr>
<tr>
<td>Hot Bearing Detector (HBD)</td>
<td>Measures surface temperature of bearing to identify defects associated to improper installation or internal damage.</td>
</tr>
<tr>
<td>Warm Bearing System (WB)</td>
<td>Rules Engine including bearing temperature trending and composites with ABD / WILD.</td>
</tr>
</tbody>
</table>
## Detector Network Overview

### Truck Evaluation

<table>
<thead>
<tr>
<th>Technology</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Truck Geometry Detector (TGD)</td>
<td>Identifies worn wheels and truck steering related issues. Can be used to identify wheel manufacturer by plate shape.</td>
</tr>
<tr>
<td>Spring / Wedge Detector (SWD)</td>
<td>Measures and inspects truck springs and friction wedges for worn, broken or missing components.</td>
</tr>
<tr>
<td>Truck Performance / Hunting Detectors (TPD / THD)</td>
<td>Measures forces applied to rail associated to poorly steering trucks or truck hunting.</td>
</tr>
</tbody>
</table>
## Detector Network Overview

### Car Body Inspection

<table>
<thead>
<tr>
<th>Technology</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Machine Vision – Undercarriage Inspection (AISC)</td>
<td>Identifies missing fasteners, broken welds and damaged structural components. Can be used to detect dragging equipment.</td>
</tr>
<tr>
<td>Machine Vision – Coupler Securement Systems:</td>
<td></td>
</tr>
<tr>
<td>• Coupler Carrier Plate (CCP)</td>
<td>Detects missing fasteners, broken welds and damaged structural components and missing cotter keys and / or cross key retainers.</td>
</tr>
<tr>
<td>• Coupler Cross Key (CCK)</td>
<td></td>
</tr>
</tbody>
</table>
Detector Network Overview

Brake Evaluation

<table>
<thead>
<tr>
<th>Technology</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Machine Vision – Brake Shoe Detector (BSD)</td>
<td>Determines presence of brake shoe, if the brakes are applied and measures remaining brake shoe thickness.</td>
</tr>
<tr>
<td>Hot / Cold Wheel Detectors (HWD / CWD)</td>
<td>Measures wheel plate temperature to identify hot or cold wheels due to dragging / sticking or ineffective brakes.</td>
</tr>
<tr>
<td>Machine Vision – Low Air Hose Detector (LAHD) *</td>
<td>Identifies low air hoses and / or hose damage.</td>
</tr>
</tbody>
</table>
## Detector Network Overview

### Wheel Inspection

<table>
<thead>
<tr>
<th>Technology</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cracked Wheel / Axle Detector (CWAD)</td>
<td>Measures the energy generated by wheels / axles to determine good from bad (cracked).</td>
</tr>
<tr>
<td>Machine Vision – Wheel Tread Detector (WTD)</td>
<td>Visually identifies wheel surface wear and / or defects.</td>
</tr>
<tr>
<td>Wheel Impact Load Detector (WILD)</td>
<td>Measures vertical wheel force on rail to identify surface defects and out-of-round.</td>
</tr>
<tr>
<td>Machine Vision – Wheel Profile Detector (WPD)</td>
<td>Measures wheel dimensions to identify worn or loose wheels.</td>
</tr>
</tbody>
</table>
New Technology – MVS TreadView
New Technology – MVS TreadView
New Technology – MVS TreadView
**New Technology – MVS Air Hose Inspection**

<table>
<thead>
<tr>
<th>Bottom Camera Raw Image</th>
<th>Bottom Camera Processed Image</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Top Camera Raw Image</th>
<th>Top Camera Processed Image</th>
</tr>
</thead>
</table>

It would be helpful long term if we could measure the length of the wear marks on the coupler shank when arrangement is stretched. This wear mark indicates the amount of wear in the coupler butt, cross key/pin, key slot/pin hole, front and rear lugs, and the yoke lugs. This wear just adds free slack to the system that must be accounted for in the air hose arrangement. The AAR is working on wear criteria for cushion unit components.

4. Use AAR rule 5 for other reference information. AAR Rule 5 is a bit broken.

12/4/15

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Car on the left has a proper glad-hand “straight shank.” Has a cushion device and stretched to the end of the trolley. In the orange circle, you can see the trolley is at full extension. In the green circle, this distance is not fixed, can be measured and in this position would be an exception because it’s pulled out to the max.

The car on the right is an old style “90 degree” glad-hand. Also stretched to the max.

Post processing – know what kind of cushion device. That will tell distance/travel of cushion device.

The photo above is awesome! It perfectly highlights the need to identify hose coupling in relation to pulling face. These are E-Head couplers and all couplers in cushioned underframe service (at least to my knowledge) will have this type of head. Note that the glad hand on the car on the left is short of the pulling face by maybe 3 inches. The trolley arrangement on this car does not allow the hose to pull out as far as it needs to. See details of E-Head couplers below (these also come in both E and F shank but basic dimension of coupler horn to pulling face (12 inches) is standard with all couplers – this dimension can be as much as 13” due to wear of knuckle and pulling lugs).
• Enhanced use of existing data
  • Incorporate all relevant data sources
  • Condition-Based, Maintenance planning
  • Composite rules leverage complementary detector data
  • Optimize detector set points and setout locations

• Continued development and use of technologies
  • Increase use of high speed imaging
  • Re-purpose / refine existing technologies
  • Explore use of emerging technologies
    • Fiber optic
    • Onboard monitoring

• Strategically expand network coverage
  • Increase detector density
    • Provides redundancy
    • Reduces spacing
    • Facilitates trending
Derailment Prevention Vision

Next Step Level Improvement?
BNSF’s Capital Investments

- **Replacement Capital**
- **Expansion**
- **PTC**
- **Locomotive**
- **Equipment**

$ Billions

<table>
<thead>
<tr>
<th>Year</th>
<th>Replacement Capital</th>
<th>Expansion</th>
<th>PTC</th>
<th>Locomotive</th>
<th>Equipment</th>
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<tr>
<td>2017P</td>
<td>$3.4</td>
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</table>
2017 Capital Investments $3.4B

- $440M (13%) Locomotive, Freight Car, & Other Equipment
- $410M (12%) Expansion & Efficiency
- $100M (3%) PTC
- $2.4B (72%) Core Network & Related Assets
Visual Inspection: Over 10 million miles of track annually visually inspected by over 650 Track inspectors
  • Many core subdivisions across the BNSF network are inspected up to 7 times per week in many cases
  • Robust Track Inspector Certification initiative

Automated Track Geometry Inspection
  • Fleet of cars for high speed laser/inertia test systems collect track condition information including Holland Star Cars which collect geometry data utilizing track loading capability
  • Generates a Surface Quality Index rating for every ¼ mile of track used to prioritize surfacing investment over time
  • Many core routes are inspected up to 6 times per year

Ultrasonic Internal Rail Flaw Detection
  • Intervals between inspections are as frequent as every 16 days on the highest density lines

Tie Inspection
  • Visioning system gathers condition of ties which is utilized to prioritize annual tie replacement cycles

Ground Penetrating Radar (GPR) Ballast Inspection
  • GPR used to plan undercutting, or 8’-10’ below rail ballast replacement, to improve support of track structure
Engineering: Track Inspection Fleet

- Track Inspection Hy-rail Vehicle
- Optical Track Inspection Car
- Track Geometry Car
- STAR Car
- UAV (Drone)
- Joint Bar Inspection Vehicle
- Aurora Tie inspection Vehicle
- Ultrasonic Hy-Rail Vehicle
- Ground Penetrating Radar
Rail Detection

- More than 200,000 miles tested per year
- Preventing broken rail service interruptions and derailments
- Uses Ultrasonic shear waves
- Suspect indications are hand-tested to verify
- Emerging technologies in:
  - Ultrasonic guided waves
  - Ultrasonic phased arrays

Track Geometry Cars

- 140,000 miles tested in 2015
- 260,000 miles tested in 2016
BNSF is one of only a few companies in the United States – and the first railroad – to take the lead in the use of Unmanned Aerial Vehicles (UAVs)

Supplemental track and structure inspection
- Small multi-rotor aircraft
- Operations governed by FAA Section 333 Exemption

Track integrity flights for key train operation
- Larger fixed wing aircraft
- Initially governed by FAA Research Agreement (CRDA)
Analytics: Engineering Dashboards

Utilization & Performance

Window Analysis vs Baselines

Visualization Tools (Territory Health)

Clustering Heat Maps
BNSF is leveraging technology and analytics more than ever with significant improvements in safety, reliability, and efficiency. However…………..

Tremendous opportunity to improve in the implementation of new technology:

• “Big Data” analytics
• The pace technology is changing makes “implementation” difficult

Lessons learned

• Legacy processes are hard to change
• Collaboration is critical
• Scope matters
  • Curve Relay
  • Predictive tags/CSP
  • Track Inspection
BNSF Needs

- Help with big data analytics
- Ballast Maintenance
  - How do we leverage GPR?
  - Track lifting versus undercutting versus surfacing; Effectiveness of SBC
  - Repeat red tags – subgrade analysis
- Concrete tie renewal strategy
- Wood tie life (asset life extension in general)
- Non-destructive rail neutral temperature measurement
- Reduce track occupancy with inspection systems
Future Technology Plays a Key Role in Driving Safety Improvements, Efficiency, and Reliability