Moving to Performance-Based Automated Track Inspection

The Benefits and Hurdles Ahead



Agenda

- BNSF System Overview
- Track Evaluation Technologies
 - Current & Future
- Information Consolidation
- Track Maintenance and Capital Replacement
- Challenges



BNSF System



- A Berkshire Hathaway company
- 32,500 route miles with operations in 28 states and 3 Canadian provinces
- 44,000 employees
- Approximately 8,000 locomotives

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- 13,000 bridges and 89 tunnels
- 1,500 freight trains per day
- Serves over 40 ports

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Geo Inspection Miles versus Derailments



Geometry Car Inspection Miles & Number of Derailments

- Main Track
- Track Caused Derailments Only
 - T001-T199, excl. T109

All Railbound Geo Car Inspections

- Gage, Alignment & Surface Defects
- Increased inspections/data have allowed Capital Planning to be more focused.....
- eliminate the squeaky wheel!



Track Evaluation Technologies

Sensor based with Evaluation Software



BNSF Geometry Car Systems





- 3 Manned Geometry Cars
- 3 Unmanned Geometry Cars
- 4 Hyrail Geometry Trucks
- 61 Locomotives with Vehicle Track Interaction (VTI)





Manned/Unmanned Geometry

Truck Mounted Geometry & Rail

Profile Beam



Laser Illumination with Multiple Cameras Multiple display screens for Field evaluation as information is collect and analyzed



<u>Unmanned</u> instrumentation the same, operated as scheduled train with buffer car





BAILWAY



Vision Evaluation Systems



Monochrome Line Scan Cameras with lighting systems





Joint Bar Inspection

Track Component Inspection



Vision Analysis - Manual to Machine Vision



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Automated Vision System

Transform the manual inspection into Condition Evaluation; Effective Remediation - Now or Planned

Rail bound comprehensive optical system capable of performing near real-time detection of rules based track conditions





Vision System Expectations



Automated determination over manual identification Bar Hole Bolt HBH|HBB Hole Defect Discontinuity **Missing Bolts** Hole Bolt **Process** Bolt Detect the Object 1. Determine exceptions based on Rules 2.

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Optical Inspection Platforms



Track Bound Systems Drone (UAV) Aerial Systems



Drone (UAV) Aerial Operations

Supplemental method for providing specific types of inspections or asset assessments.

- Service Interruption support
- Slope and material buildup monitoring
- Distance, volume & area assessments
- Water runoff direction and flow rate determination



UAS "Go Team"

- 24/7/365 45 Minute Notice from Call to Readiness
 - First responder and remediation support + data services
 - Aircraft and support systems readied for corporate jet fleet









UAS Bridge Inspection

Automatic detection and notification of faults:

- Missing rivets
 Cracks in concrete
 Rust bleeding
- Excessive corrosion / pitting
- Cracks in steel
- Automatic pixel-level change detection:
 - Change in rust bleeding pattern
 Change or deformation of structural components





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UAS Water Flow Monitoring

Material Buildup affecting Water Flow





UAS Measure & Profile

Birmingham Quarry point cloud from Imagery



Monitor distance between track and Quarry ledge







Light Detection and Ranging (Lidar)

System to Physically Measure, Classify Track Structure and Identify Objects

- PTC Asset Mapping
- Track Asset Management
- High-Wide Clearance
- Drainage Profiles
- Turnout Condition Assessment
- Ballast Profile





Ground Penetrating Radar (GPR)

Rail bound collection with post processing analysis for producing Ballast Fouling Index (BFI)



Two shoulder & two center antennas



Antenna Frequency determines depth evaluation



Future Technologies

In the works and need more development



Today's Automation Development

Sensor Selection



Mechanical Engineering



Edge Computing



Edge Software



Cloud Processing



Machine Vision Analytics





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Comprehensive Evaluation Platforms

Vehicles that collect multiple types of condition data in a single pass









What's next

- Autonomous Measurement technology
 - New types of Lidar and Cameras from Automotive Industry
- Locomotive technology expansion
 - Full Geometry, Vision, etc.
- Sensors; Multiple types of Radar, Cameras that capture information beyond visible light
- Space born imagery and sensor data



Challenges

Current & Future



Data Alignment











Increasing the value of a single data source by aligning with others to provide better insight to track conditions



The Challenges

- What problem is one trying to solve; Use Case?
 - What technology will provide insight to the problem
 - Not always about new data but solving with what data one has!
- Data movement & management
 - What needs to be kept for analysis?
 - Resolution of imagery; analysis versus user view
- Aggregation & Consolidation of Data for extracting additional Value
 - Data is siloed in multiple repositories in many places
- Change management to educate affected users who can best utilize



Track Condition Data Aggregation

Planning/Monitoring Systems



Comprehensive Surfacing Plan (CSP)

Current State:

- Answers the question of "where should I surface?" for division capital surfacing work
- Machine Learned process that incorporates geometry parameters with curve geometry then linkage rules
- Displayed on strip charts, track charts and Tableau reports



Improvement Opportunities:

- Adoption of the new model
- Threshold driven vs. Machine learned

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Comprehensive Surfacing Plan (CSP)

Common Track Chart Report Visualization

- Priority (6,352 miles)
 - Firefighter: Reds & Oranges
 (20%)
 - Reactive: Yellows, Over elevated curves +1" (28%)
 - Proactive: All others (52%)
- Lists fixed assets with in limits





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Future of Comprehensive Surfacing Plan (CSP)

at Workday EC

and confederate bill or or

DUDIEY

- Solving for reporting of work locations vs CSP recommendations
 - Logical solution is from Compass on tampers

Track Chart Visualization

90 CUL 24' 55 AEI (2)

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 Provides quick feedback and validation on tools

> I CUL 48" X 1"CP 1 NO. 11 T.O. (2320 3 SG INTR (2)

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#### **Strip Chart Visualization**

**WRI** 20019



# **Existing Data- Curve Model**

Predicts rail wear using regression modeling:

- Rail wear from geometry car
- Tonnage (MGT)
- Degree of Curvature
- Model is not linear, accommodates acceleration of wear









### **Curve Model**

- Today Predicting Rail Wear Challenges:
  - Track Alignment
  - Rail Weight Discrepancies
  - Train model data sets
- **Development**: Implements rail wear discrepancy fixes
- **Presentation**: represent the data on Engineering track charts and Tableau reports



**WRI 20**19



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# Predictive Analytics – Orange Tags

Orange Tags were developed to focus inspections and help prioritize surfacing behind a Geometry Car. Orange Tags represent track conditions that have <u>higher priority</u> than Yellow Tags but do not reach Red Tag limits.

#### **Determination Method?**

Predictive analytics are utilized with Surface Yellow Tags to predicts whether or not the Yellow Tag will turn Red in 30 days. The Surface parameters include cross level, surface and alignment with warp soon to come.

#### **Outside of Surface Parameters**

Gage, Cant and Rail Wear have Orange Tag limits established half way between Red & Yellow.



### **Tie Replacement Capital Program**

- Tie replacement determined by auto condition assessment
- Data is analyzed, massaged, loaded into database
- Tie inspect, determines the condition bracket; good, marginal, maintenance, failed
- This data is downloaded to a handheld device for marking 2018 ~3M Ties
- Ties are distributed via/GPS location
- BNSF tie gangs utilize app to mark ties



**WRI** 20019



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### **Tie Marking Process Improvement**

#### <u>Latest</u>

- Plans audited and updated in inspection system
- <u>Skip</u> Intermediate marking process





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# **Turnout Reliability**

- Compiles various inspection data that speak to the condition of a turnout
- Developed scoring metric for different exceptions/data points
- Intent is to direct joint inspections (track-signal) and validate Capital mtce/replacement
- ~\$40M in capital replacements each year

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| RACK Multiple values) •  SFI Multiple                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Turnout Su<br>Division         | OK<br>mmary.<br>SUB<br>ABERDEEN | SOK<br>LINE_SEG_N<br>2001 | Value<br>Value<br>MILE_POST<br>514.003                                                                                                                                                      | TRACK<br>Single                                                                                                                                   | 200K<br>TRACK_SDT<br>0                                                             | T., CNTRL_PT<br>SIOUX CITY                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Switch Tag Id<br>0502E                                                                                                                                    | ITV BWA                                                                        | Avg. 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| RACK<br>Multiple values) • •<br>EFF (Multiple,O_25<br>CSP Count = 1<br>SEO YelloO_5<br>SEO YelloO_5<br>SEO Orang 1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Turnout Su                     | OK<br>mmary.<br>SUB<br>ABERDEEN | SOK<br>LINE_SEG_N<br>2001 | Value<br>Value<br>MILE_POST<br>514.003<br>514.689                                                                                                                                           | TRACK<br>Single<br>Single                                                                                                                         | 200K<br>TRACK_SDT<br>0<br>0                                                        | T., CNTRL_PT<br>SIOUX CITY<br>SIOUX CITY                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Swtch Tag Id<br>0602E<br>0603W                                                                                                                            | ITV. 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MILE_POST<br>514.003<br>517.416<br>519                                                                                                                                                    | TRACK<br>Single<br>Single<br>Single<br>Single                                                                                                     | 200K<br>TRACK_SDT<br>0<br>0<br>0<br>0                                              | T., CNTRL_PT<br>SIOUX CITY<br>SIOUX CITY<br>N SIOUX CITY<br>N SIOUX CITY                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            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| MACK  HARDEVAUUE)  IF/ Multiple, (orgs  CSP Count =, [1  GEO Yellow Gos  GEO Orange, [1  GEO Red T, [3  Rail Delect =, [3                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Turnout Su                     | OK<br>mmary.<br>SUB<br>ABERDEEN | LINE_SEG_N<br>2001        | . MILE_POST<br>514.003<br>517.416<br>519<br>519.846                                                                                                                                         | TRACK<br>Single<br>Single<br>Single<br>Single<br>Single                                                                                           | 200K<br>TRACK_SD1<br>0<br>0<br>0<br>0<br>0                                         | T., CNTRL_PT<br>SIOUX CITY<br>SIOUX CITY<br>N SIOUX CITY<br>N SIOUX CITY<br>N SIOUX CITY                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            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| RACK URSPLANDED USPLANDEDUCE US | Turnout Su                     | OK<br>mmary.<br>SUB<br>ABERDEEN | LINE_SEG_N<br>2001        | 100K<br>Value<br>MILE_POST<br>514.003<br>514.609<br>517.416<br>519<br>519.846<br>520.68                                                                                                     | TRACK<br>Single<br>Single<br>Single<br>Single<br>Single<br>Single                                                                                 | 200K<br>TRACK_SD1<br>0<br>0<br>0<br>0<br>0<br>0                                    | T., CNTRL_PT<br>SIOUX CITY<br>SIOUX CITY<br>N SIOUX CITY<br>N SIOUX CITY<br>N SIOUX CITY<br>N SIOUX CITY                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Switch Tag Id<br>0602E<br>0603W<br>0606E<br>9925E<br>0608E<br>9928W                                                                                       | LLA 'BAY<br>0.0<br>0.0<br>0.0<br>0.0<br>0.0                                    | Avg. 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[3                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Turnout Su                     | OK<br>mmary.<br>SUB<br>ABERDEEN | LINE_SEG_N<br>2001        | 100K<br>Value<br>MILE_POST<br>514.003<br>514.689<br>517.416<br>519<br>519.846<br>520.68<br>520.68<br>528.956                                                                                | TRACK<br>Single<br>Single<br>Single<br>Single<br>Single<br>Single<br>Single<br>Single                                                             | 200K<br>TRACK_SDT<br>0<br>0<br>0<br>0<br>0<br>0<br>0                               | T CNTRL_PT<br>SIOUX CITY<br>SIOUX CITY<br>N SIOUX CITY<br>N SIOUX CITY<br>N SIOUX CITY<br>N SIOUX CITY<br>N SIOUX CITY<br>NORTH JEFF.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Switch Tag Id<br>0602E<br>0603W<br>0606E<br>9925E<br>0608E<br>9926W<br>6051E                                                                              | LA BW<br>0.0<br>0.0<br>0.0<br>0.0<br>0.0<br>0.0                                | Avg. 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| MACK MARPHANDEN OFF Mumphul (0.25 OFF Count = [ GO Venio. [ GO Ven | Turnout Su                     | OK<br>mmary.<br>SUB<br>ABERDEEN | LINE_SEG_N<br>2001        | MILE_POST<br>514.003<br>514.609<br>517.416<br>519.846<br>520.68<br>528.956<br>530.52                                                                                                        | TRACK<br>Single<br>Single<br>Single<br>Single<br>Single<br>Single<br>Single<br>Single                                                             | 200K<br>TRACK_SDT<br>0<br>0<br>0<br>0<br>0<br>0<br>0<br>0<br>0<br>0<br>0<br>0<br>0 | F. 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| AACK HADRE SHOTS IFI Multiple. [0.25 FF Outline.] FF Multiple.] EAD Vello[0.5 EAD Vello[0.5 EAD Outline.] EAD Ref T[3 EAD Ref T[3 EAD Mether.] SAM Defect[2 EAD Mether.] EAD Mether.[2] EA                | Turnout Su                     | OK<br>mmary.<br>SUB<br>ABERDEEN | SOK<br>LINE_SEG_N<br>2001 | MILE_POST<br>514.003<br>514.003<br>514.609<br>519.519<br>519.846<br>520.68<br>520.68<br>520.65<br>533.453<br>533.453                                                                        | TRACK<br>Single<br>Single<br>Single<br>Single<br>Single<br>Single<br>Single<br>Single                                                             | 200K<br>TRACK_SD1<br>0<br>0<br>0<br>0<br>0<br>0<br>0<br>0<br>0<br>0<br>0<br>0<br>0 | T., CNTRL_PT<br>SIOUX CITY<br>N SIOUX CITY | Swtch Tag Id<br>0002E<br>0003W<br>0606E<br>9925E<br>0608E<br>9920W<br>6051E<br>6051E<br>6051W<br>6199E                                                    | LIA 10AV<br>0.0<br>0.0<br>0.0<br>0.0<br>0.0<br>0.0<br>0.0<br>0.0<br>0.0        | 0.0 V00 Bernedy 0.0 V00 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| ACK Hittiger shares) HT Muttiger, (o 25 HT Muttiger, (o 25 HT Muttiger, (o 25 HT Muttiger, (o 25 HT Muttiger, (o 5 HT Muttiger, (o 15 HT Muttiger, | Turnout Su                     | OK<br>mmary.<br>SUB<br>ABERDEEN | 50K<br>LINE_SEG_N<br>2001 | MILE_POST<br>514.003<br>514.003<br>517.416<br>520.68<br>520.68<br>520.68<br>520.68<br>530.52<br>533.453<br>564.375<br>564.375                                                               | TRACK<br>Single<br>Single<br>Single<br>Single<br>Single<br>Single<br>Single<br>Single<br>Single<br>Single                                         | 200K<br>TRACK_SD1<br>0<br>0<br>0<br>0<br>0<br>0<br>0<br>0<br>0<br>0<br>0<br>0<br>0 | F., CNTRL_PT<br>SIOUX CITY<br>SIOUX CITY<br>N SIOUX CITY<br>N SIOUX CITY<br>N SIOUX CITY<br>N SIOUX CITY<br>NORTH JEFF.<br>NORTH JEFF.<br>SOUTH WYEL<br>GAYVILLE<br>GAYVILLE                                                                                                                                                                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| ACK Virger sites) Vir Multiple, [0.25 Virger sites] Vir Multiple, [0.25 Virger sites] Virger sites Virger sit | Turnout Su<br>Division<br>Null | OK<br>mmary.<br>SUB<br>ABERDEEN | 50K<br>LINE_SEG_N<br>2001 | MILE_POST<br>514.003<br>517.416<br>519.846<br>520.68<br>520.68<br>520.68<br>520.68<br>530.453<br>533.453<br>554.374<br>572.783                                                              | TRACK<br>Single<br>Single<br>Single<br>Single<br>Single<br>Single<br>Single<br>Single<br>Single<br>Single<br>Single                               | 200K<br>TRACK_SDT<br>0<br>0<br>0<br>0<br>0<br>0<br>0<br>0<br>0<br>0<br>0<br>0<br>0 | T., CNTRL_PT<br>SIOUX CITY<br>SIOUX CITY<br>N SIOUX CITY<br>N SIOUX CITY<br>N SIOUX CITY<br>NORTH JEFF.<br>NORTH JEFF.<br>GAYVILLE<br>GAYVILLE<br>GAYVILLE                                                                                                                                                                                                                       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**WRI** 20019

### Future Maintenance Benefits

- Assessment with Automated Evaluation
  - Reduce field evaluation
- Defined remedial actions based on condition
- Tonnage & Environmental factors to predict degradation
- Reduce field review for Capital Planning
  - Allows Virtual Field Inspection



### Affects to Work Process

- Capital Planning process change consistency
- MOW Work process change
  - Move away from exception based repairs
  - Why do I need to fix a condition that's not a defect?
- Define what needs to be corrected
- Providing field with clear understandable communication



