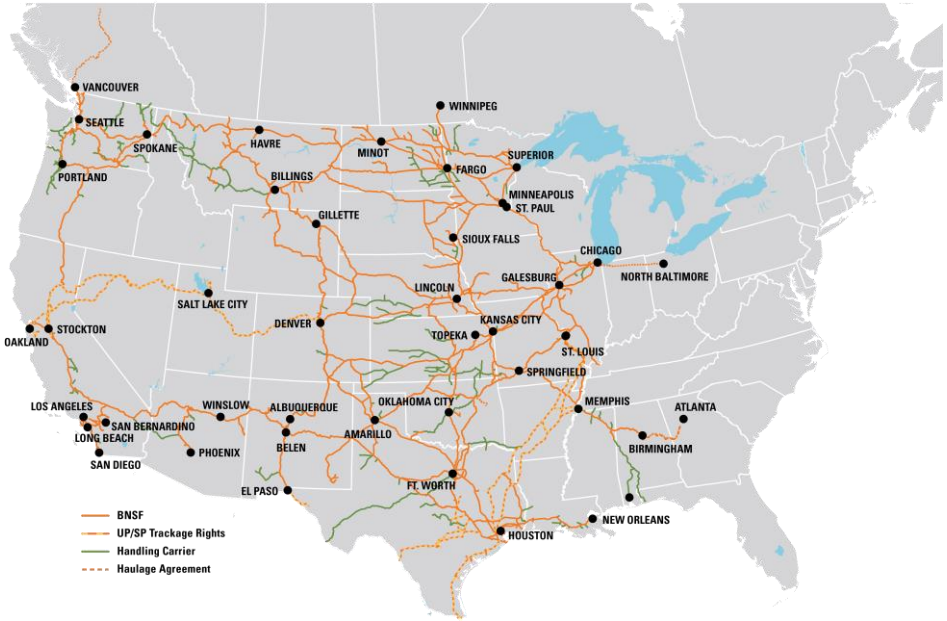
Moving to Performance-Based Automated Track Inspection

The Benefits and Hurdles Ahead

Agenda

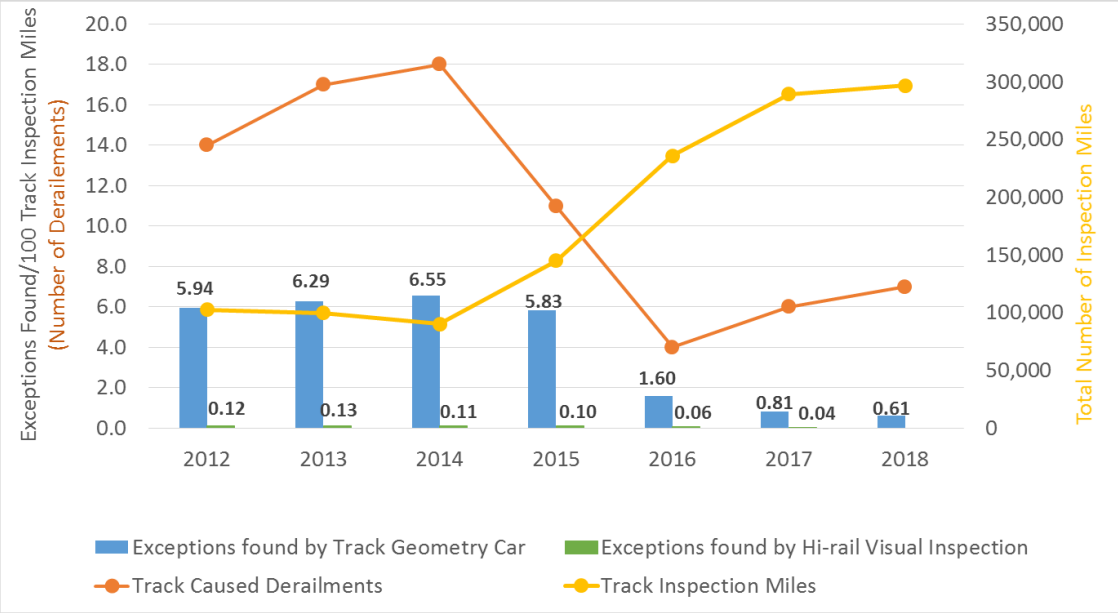
- BNSF System Overview
- Track Evaluation Technologies
  - Current & Future
- Information Consolidation
- Track Maintenance and Capital Replacement
- Challenges

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

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

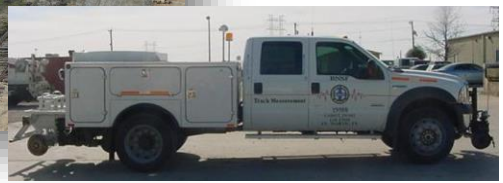
- Gage, Alignment & Surface Defects

- 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



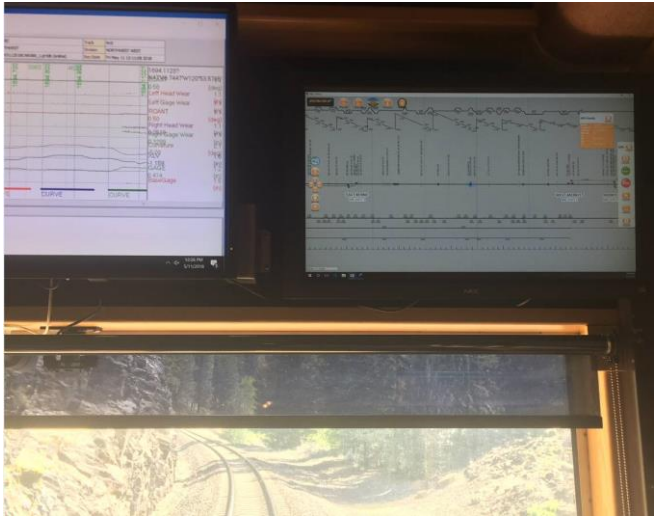
- 3 Manned Geometry Cars
- 3 Unmanned Geometry Cars
- 4 Hyrail Geometry Trucks
- 61 Locomotives with Vehicle Track Interaction (VTI)

Manned/Unmanned Geometry

Truck Mounted Geometry & Rail Profile Beam

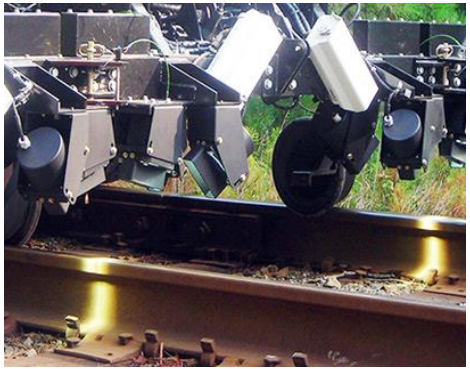
Laser Illumination with Multiple Cameras

Multiple display screens for Field evaluation as information is collect and analyzed



Unmanned instrumentation the same, operated as scheduled train with buffer car

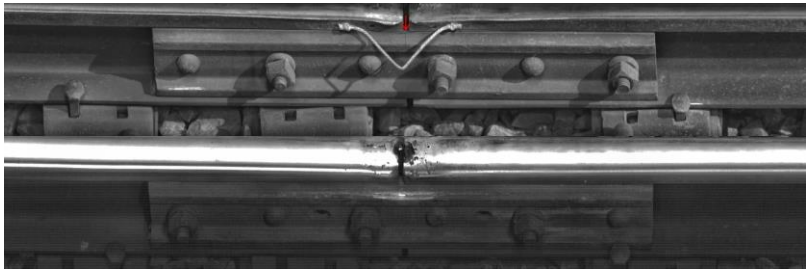
Vision Evaluation Systems

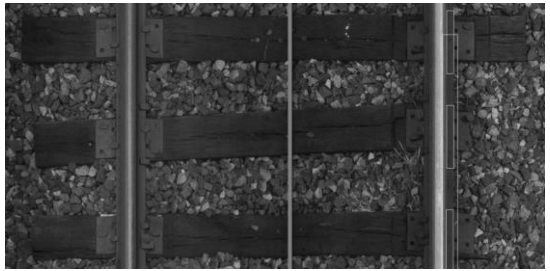


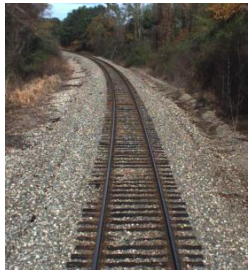
Monochrome Line Scan Cameras with lighting systems

Joint Bar Inspection

Track Component Inspection







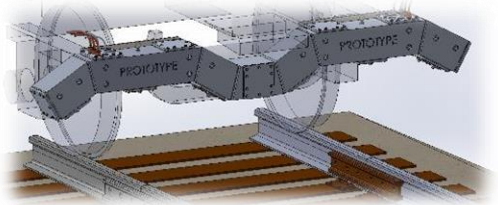
Vision Analysis - Manual to Machine Vision

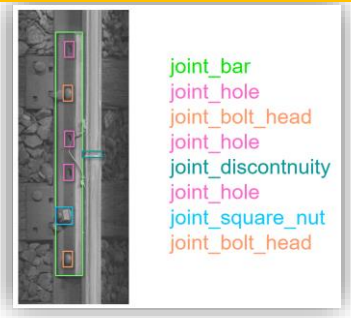
Automated Vision System

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

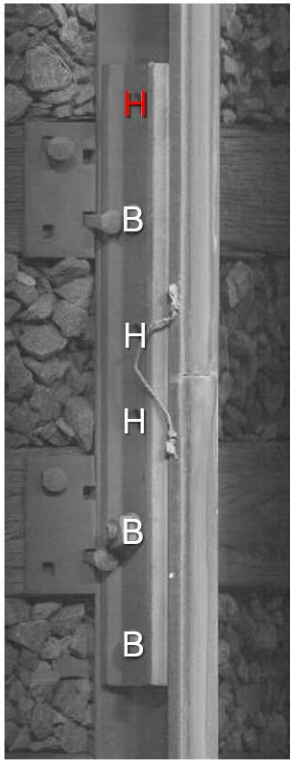
Rail bound comprehensive optical system capable of performing near real-time detection of rules based track conditions

Collect	Automate Analysis	Plan Remediation





Vision System Expectations



Bar
- Hole
- Bolt
- Hole
- Discontinuity
- Hole
- Bolt
- Bolt

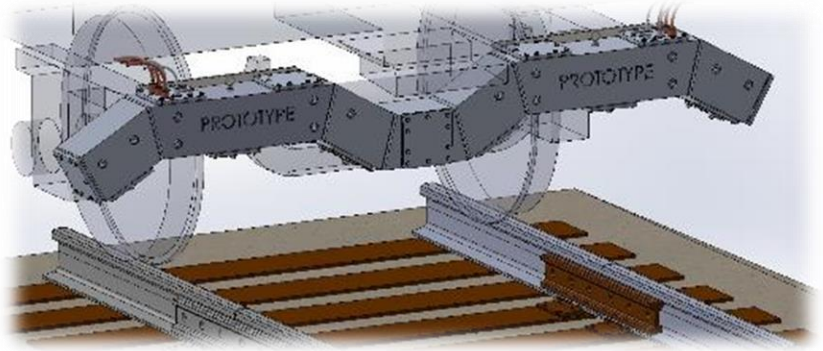
Automated determination over manual identification

H B H | H B B
Defect
Missing Bolts

Process

1. Detect the Object
2. Determine exceptions based on Rules

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

13

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

14

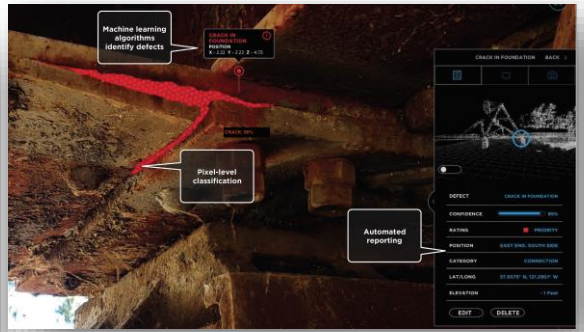
UAS Bridge Inspection

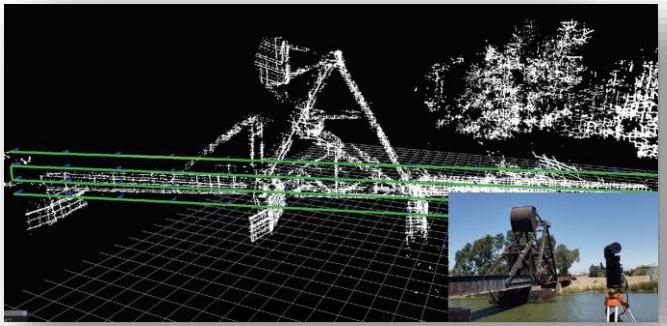
Automatic detection and notification of faults:

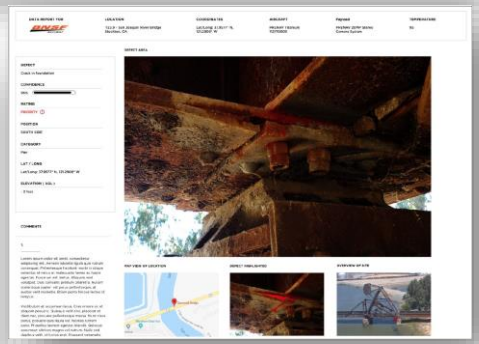
- ❑Missing rivets
- ❑Cracks in concrete
- ❑Rust bleeding
- ❑Excessive corrosion / pitting
- ❑Cracks in steel

Automatic pixel-level change detection:

- ❑Change in rust bleeding pattern
- ❑Change or deformation of structural components



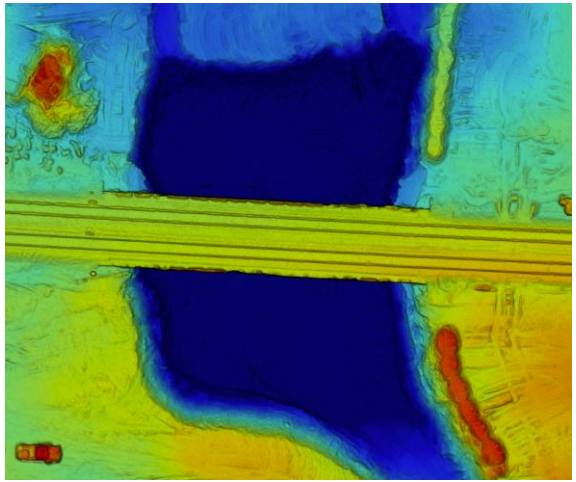




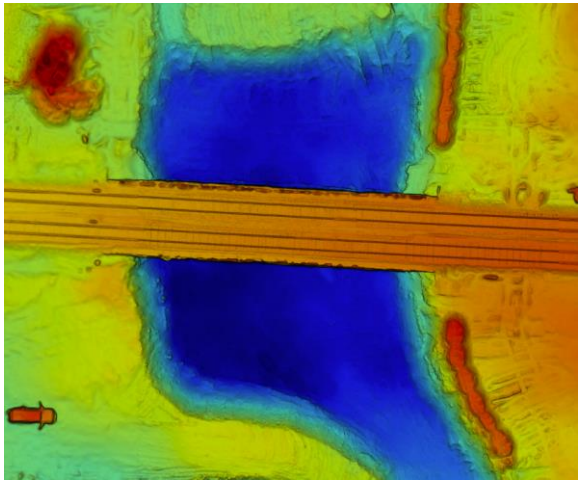
UAS Water Flow Monitoring

Material Buildup affecting Water Flow

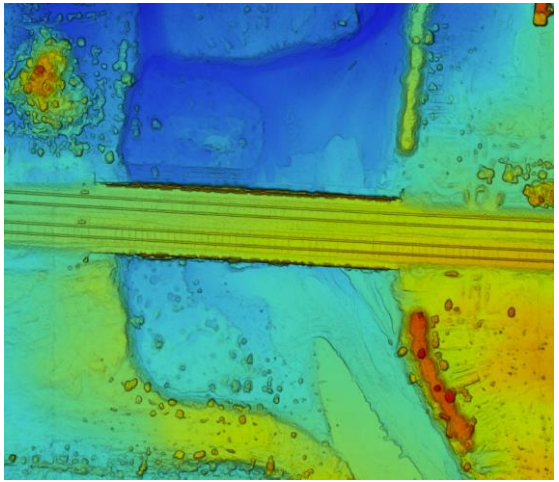
Dec 2017



Jun 2018

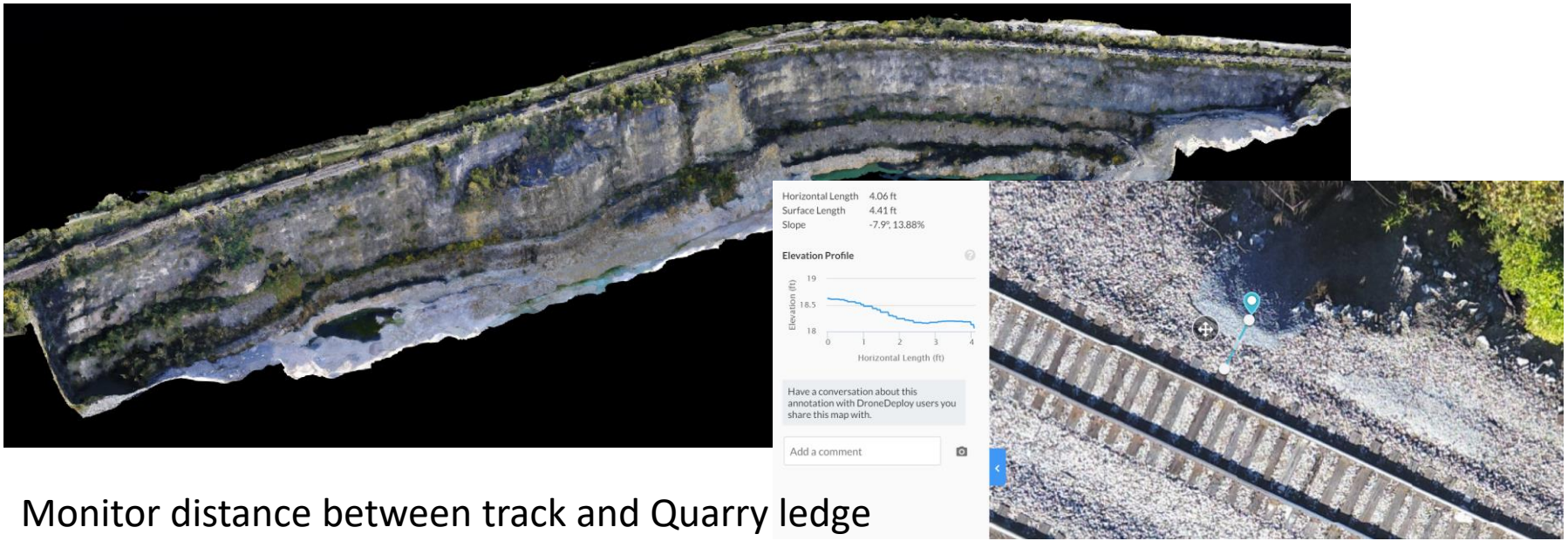


Nov 2018



UAS Measure & Profile

Birmingham Quarry point cloud from Imagery

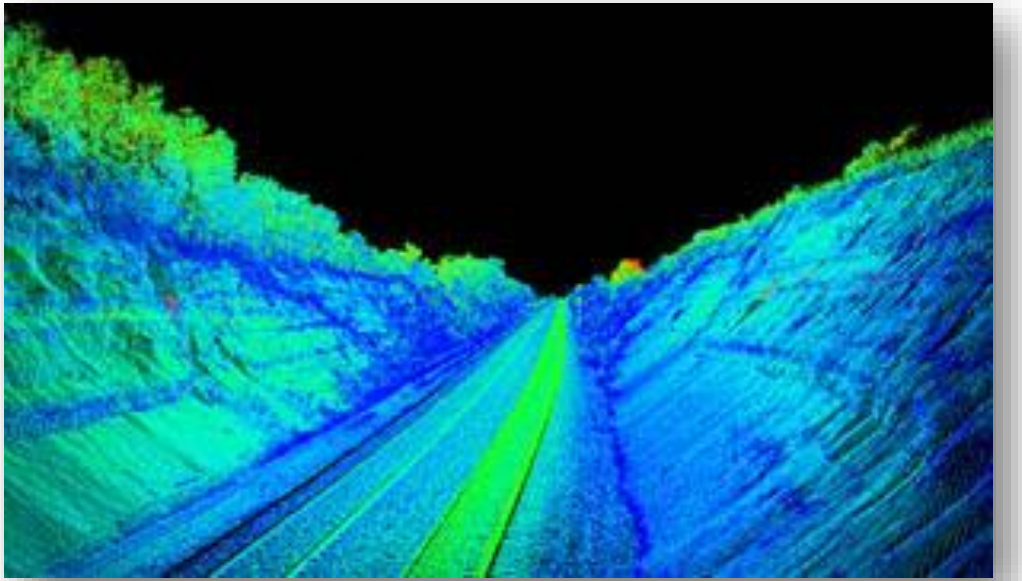


Monitor distance between track and Quarry ledge

Light Detection and Ranging (Lidar)

System to Physically Measure, Classify Track Structure and Identify Objects

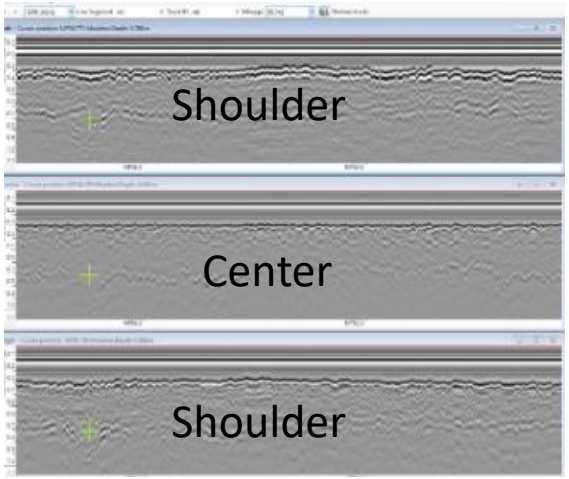
- PTC Asset Mapping
- Track Asset Management
- High-Wide Clearance
- Drainage Profiles
- Turnout Condition Assessment
- Ballast Profile



Ground Penetrating Radar (GPR)

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

Two shoulder & two center antennas



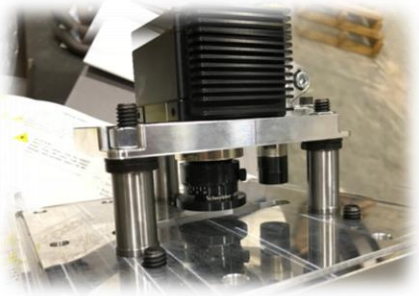
Antenna Frequency determines depth evaluation

Future Technologies

In the works and need more development

Today's Automation Development

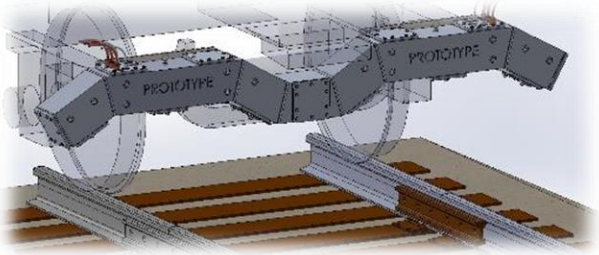
Sensor Selection



Edge Computing

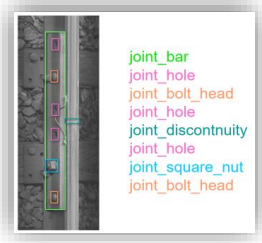
Cloud Processing

Mechanical Engineering



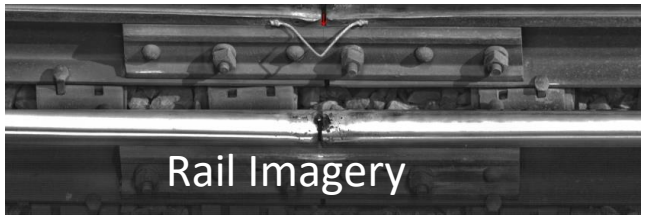
Edge Software

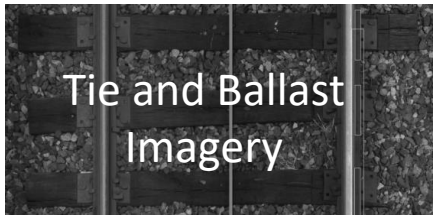
Machine Vision Analytics

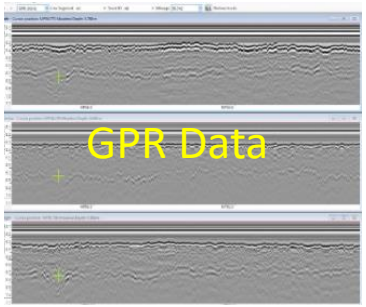


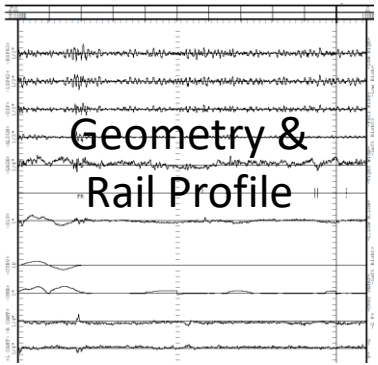
Comprehensive Evaluation Platforms

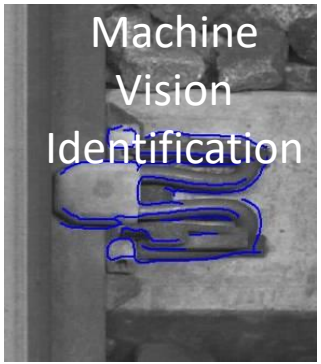
Vehicles that collect multiple types of condition data in a single pass











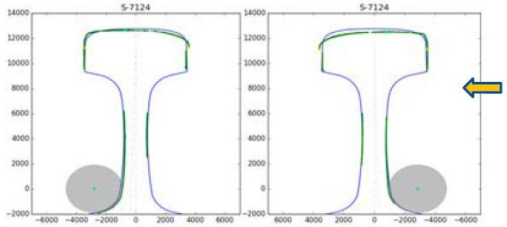
What's next

- 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

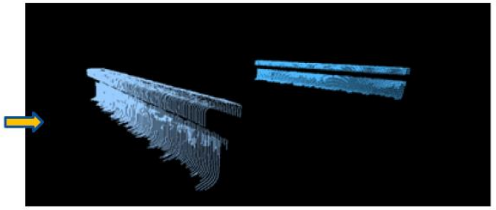
Current & Future

Data Alignment



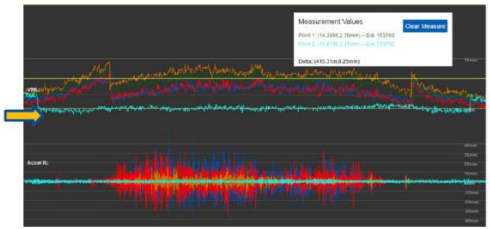
Profile

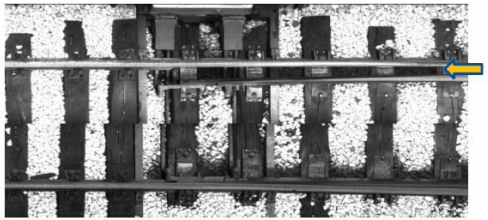
Point Cloud



Video

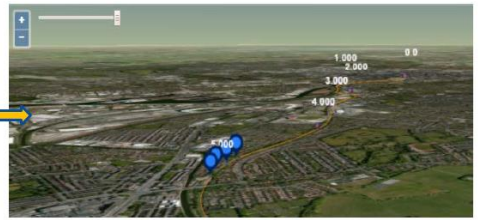
Linear Data





Imagery

Map & Schematics



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:

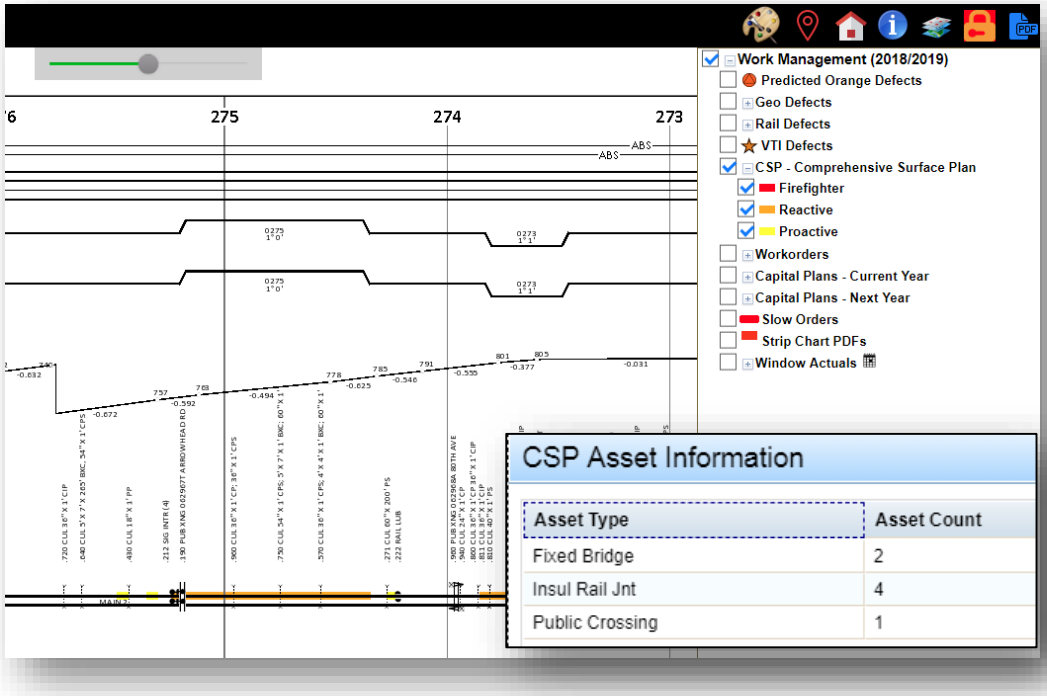
- Adoption of the new model
- Threshold driven vs. Machine learned

Comprehensive Surfacing Plan (CSP)

- **Priority (6,352 miles)**
  - **Firefighter**: Reds & Oranges (20%)
  - **Reactive**: Yellows, Over elevated curves +1” (28%)
  - **Proactive**: All others (52%)

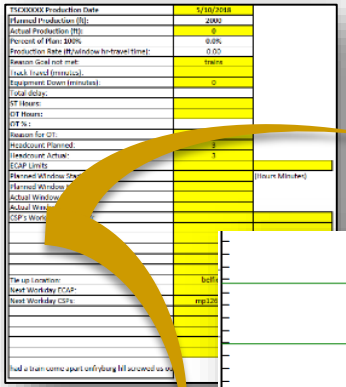
- Lists fixed assets with in limits

Common Track Chart Report Visualization

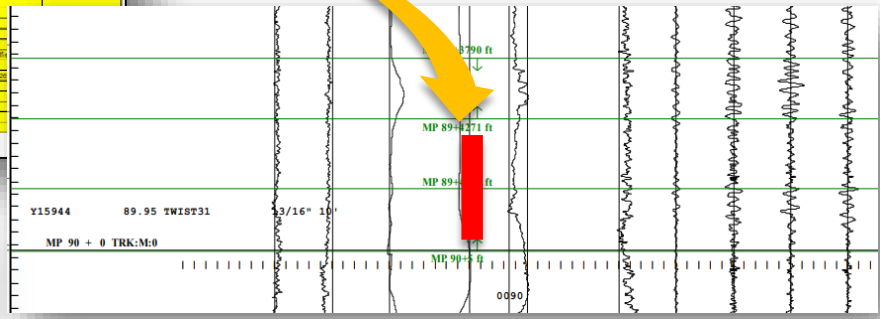


Future of Comprehensive Surfacing Plan (CSP)

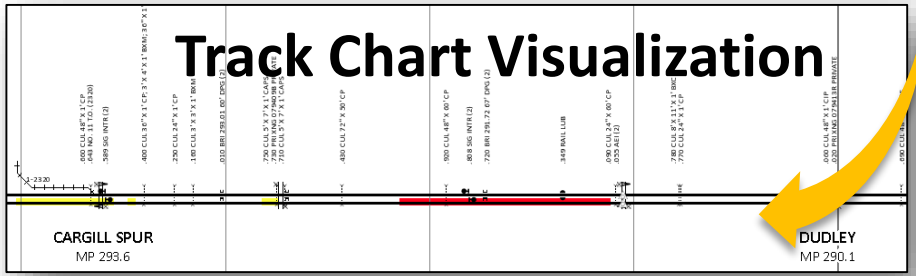
- Solving for reporting of work locations vs CSP recommendations
  - Logical solution is from Compass on tampers
- Provides quick feedback and validation on tools



MOW Work Order



Strip Chart Visualization

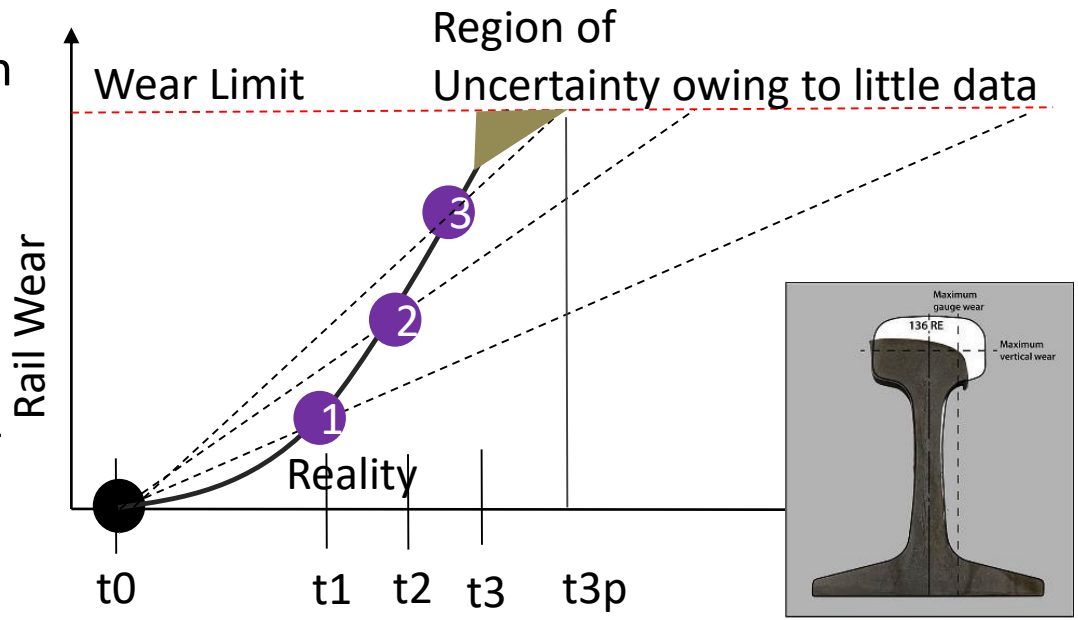


Track Chart Visualization

Existing Data- Curve Model

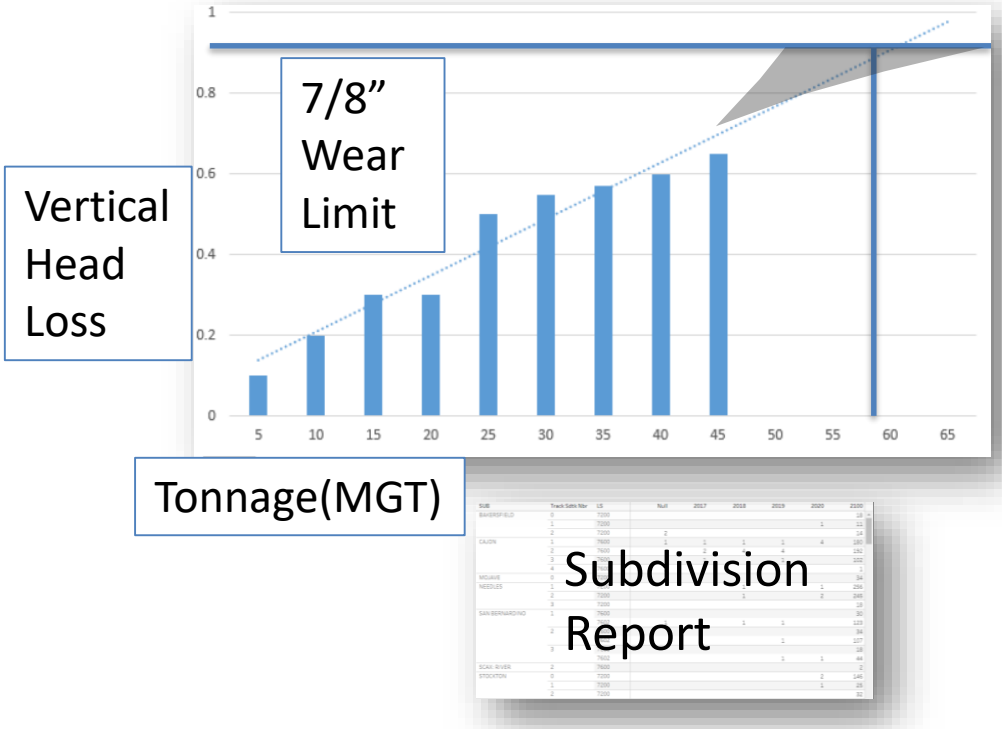
Predicts rail wear using regression modeling:

- 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



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 higher priority 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

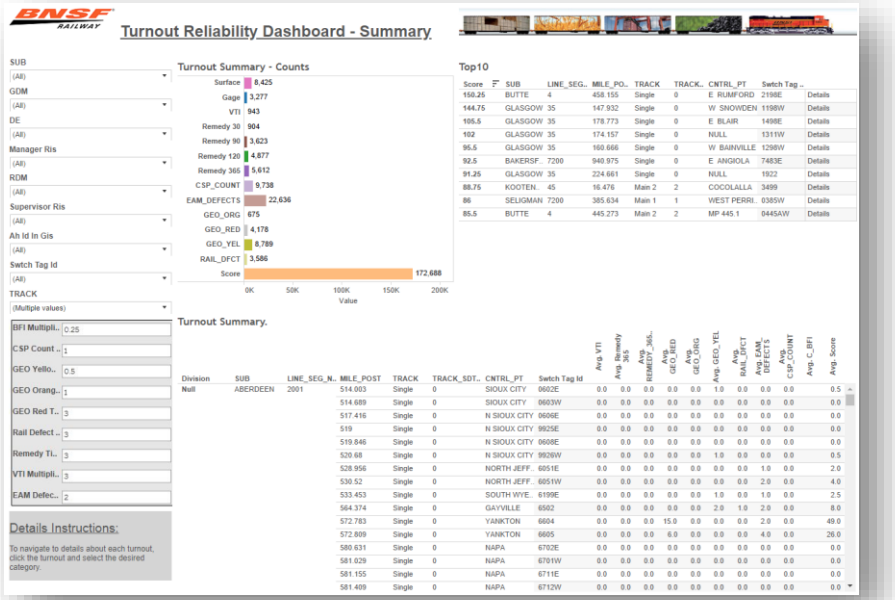
Tie Marking Process Improvement

Latest

- Plans audited and updated in inspection system
- Skip Intermediate marking process

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



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


BNSF
RAILWAY
6074
6074
6040
6040
BNSF
BNSF
6074
6040