Track Performance and Degradation Monitoring Technologies

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UNIVERSITY OF HARTFORD

Inspection

- Visual
- Geometry
- Gage Restraint Measurement
- Ground Penetrating Radar
- Track Deflection

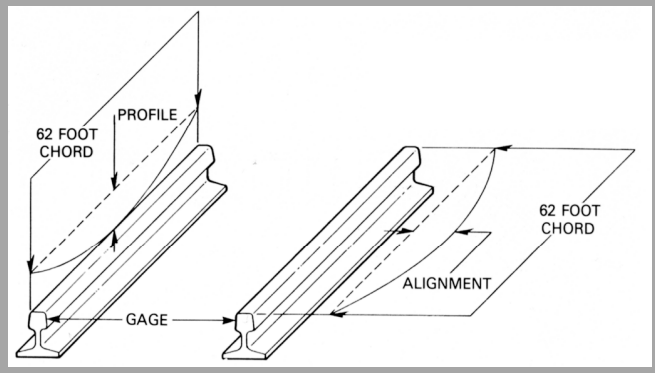
Deflection GRMS Geometry GPR Imaging: Roadbed ROW

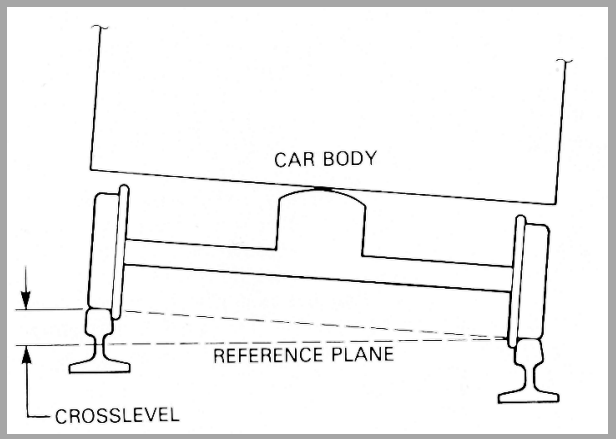
Visual Inspection

- Hy-rail / Walk
- Observe:
  - ROW
    - fences, drainage...
  - track structure condition
    - rails, ties, fasteners, joints
  - geometry

Track Geometry Measurement

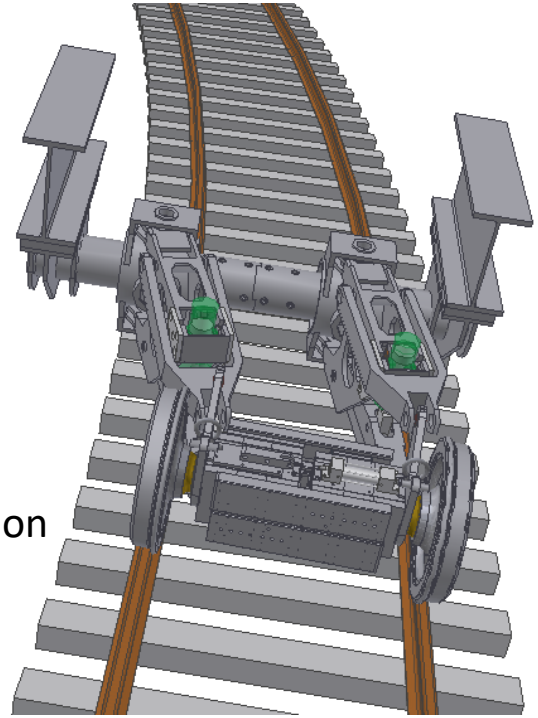
- Rail Position
  - Profile, Alignment
  - Gage, Crosslevel
- Autonomous

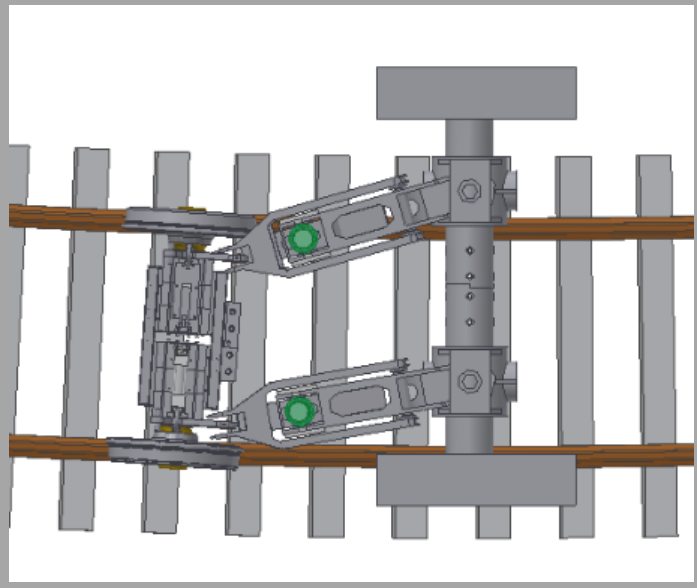




Gage Restraint Measurement System (GRMS)

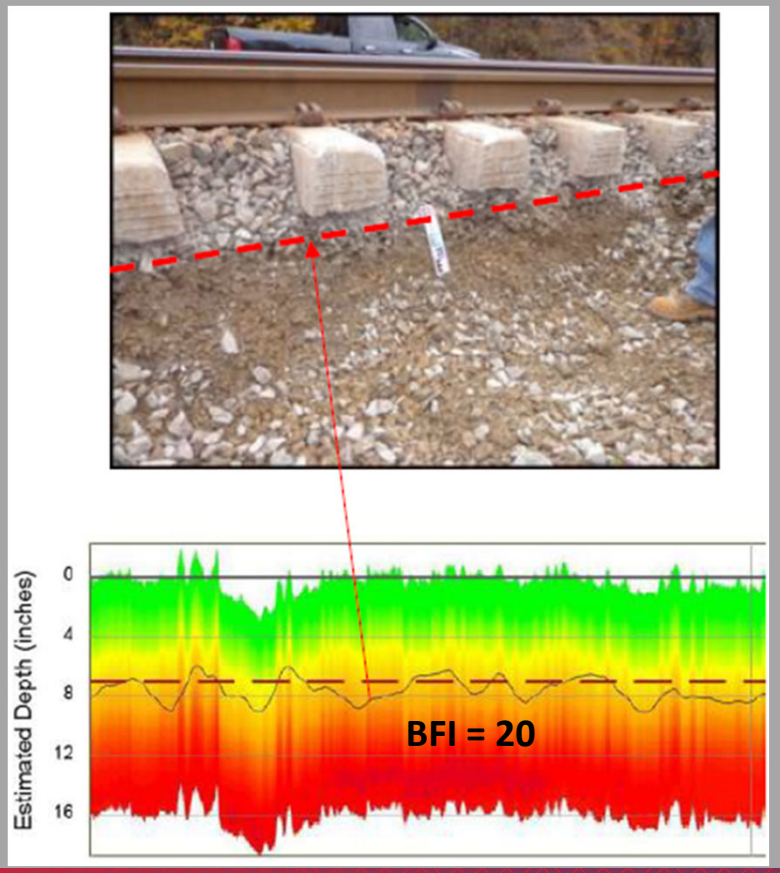
- Split axle nominally applies:
  - Lateral Force 14kips
  - Vertical Force 21kips
  - L/V = ~0.7
  - Actual Forces Measured
- Produces:
  - Gage Widening Projection (GWP)
  - Projected Loaded Gage (PLG24)





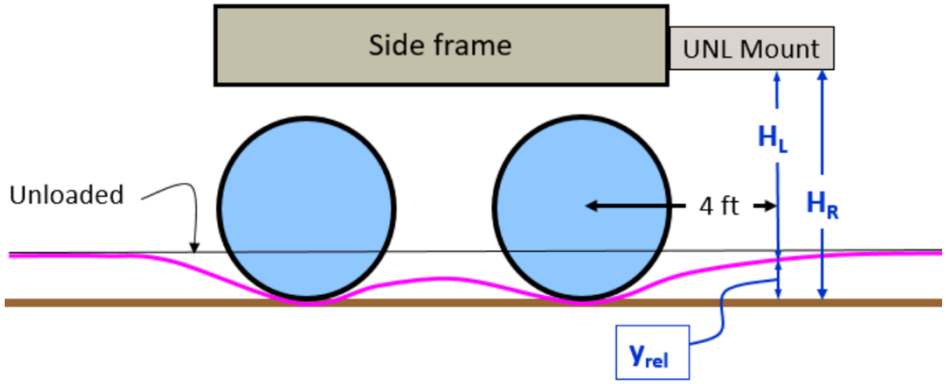
Ground Penetrating Radar (GPR)

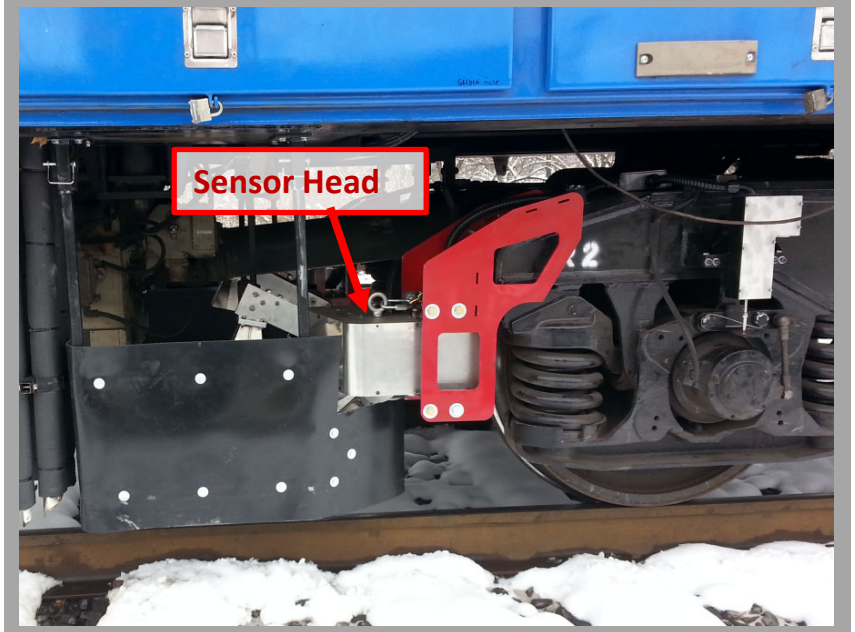
- GPR Parameters
  - Ballast Fouling Index (BFI)
    - 2 GHz Antenna
  - Ballast Thickness Index (BTI)
    - 400 MHz and 2 GHz
  - Layer Roughness Index (LRI)
  - Free Draining Layer (FDL) Depth Index
- Moisture Detection
  - (400 MHz and 2 GHz)
- Free Draining Layer Depth (FDL)
  - Thickness of clean ballast to assess:
    - Drainage
    - Moisture damage to wood ties
    - Subgrade deformation potential
  - Based on BFI using threshold of 20
- Supplied by Balfour Beatty Rail / Zetica produces several metrics that characterize track
- Upcoming: Real-time FDL



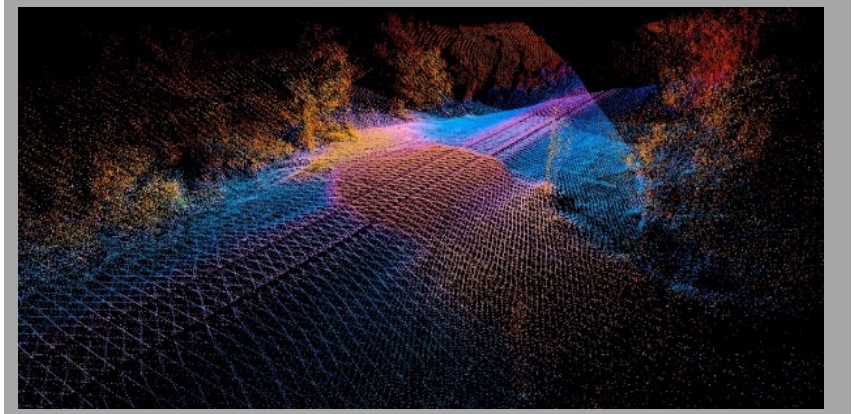
Vertical Track Deflection Measurement System (VTDMS)

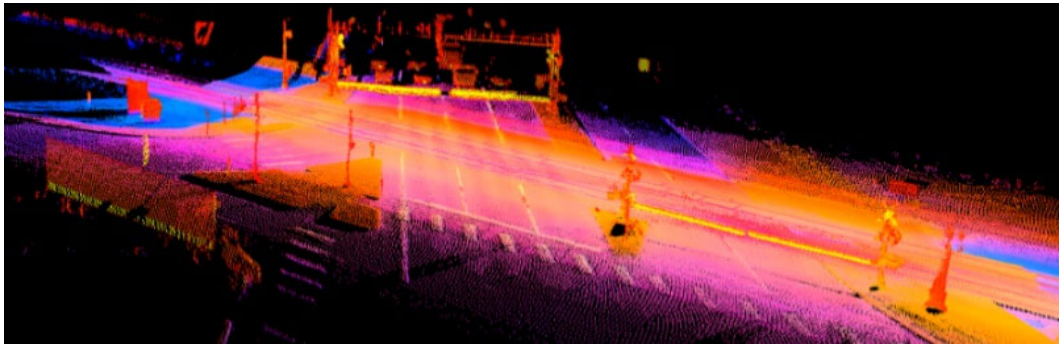
- Developed by the University of Nebraska-Lincoln under grant from FRA; commercialized by MRail and available through Harsco Rail.
- System measures a component of the total vertical deflection of a rail.

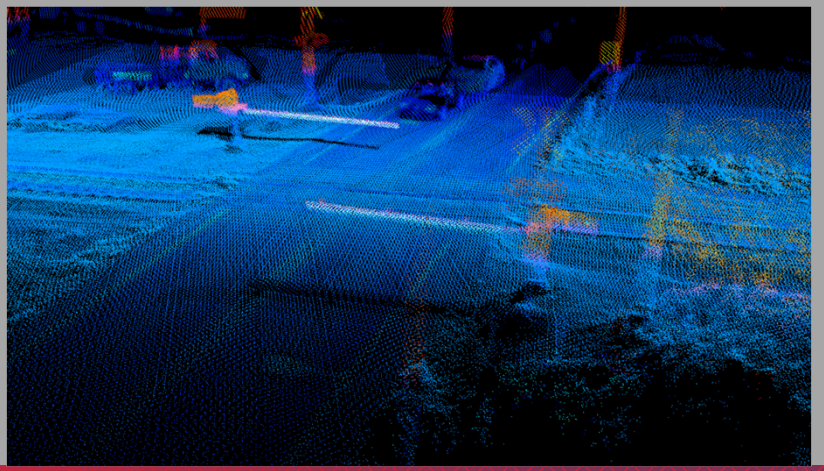




LIDAR

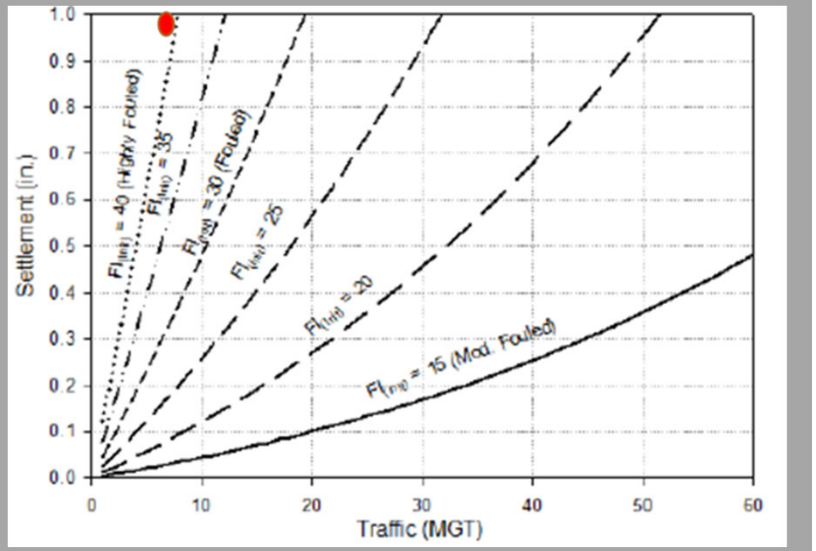






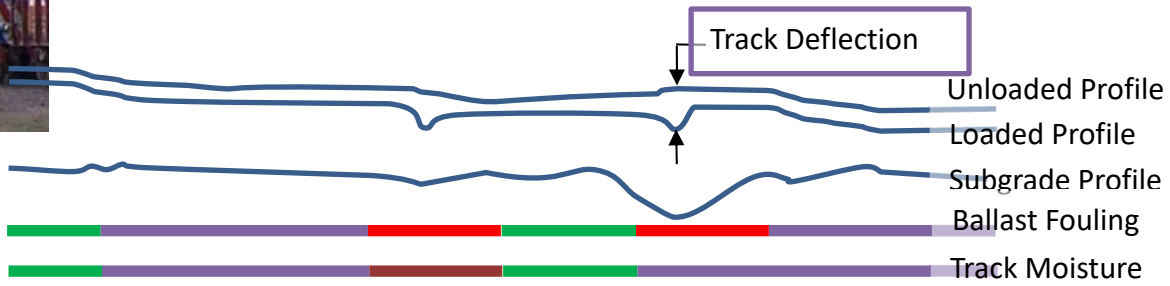
Comprehensive Inspection

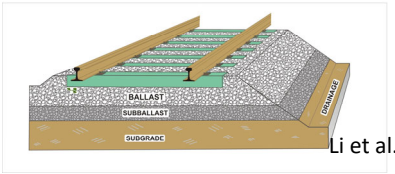
- Goal: quantify basic engineering parameters
- Provide means to assess track substructure properties during inspection and investigations
- Data can be used to understand track behavior → improved safety
  - Information that can determine root cause of track conditions and inform remedial actions
  - Data that can be used to develop objective rules



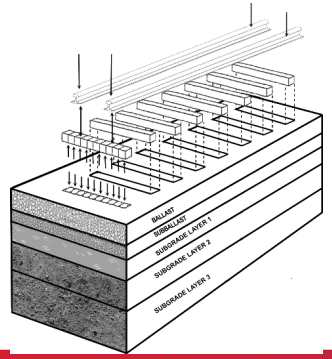
Kashani and Hyslip, 2018

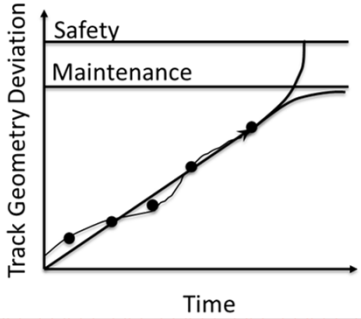
Goal: Single Pass Track Structural Inspection Informing Predictive Analytics *(4.0)*





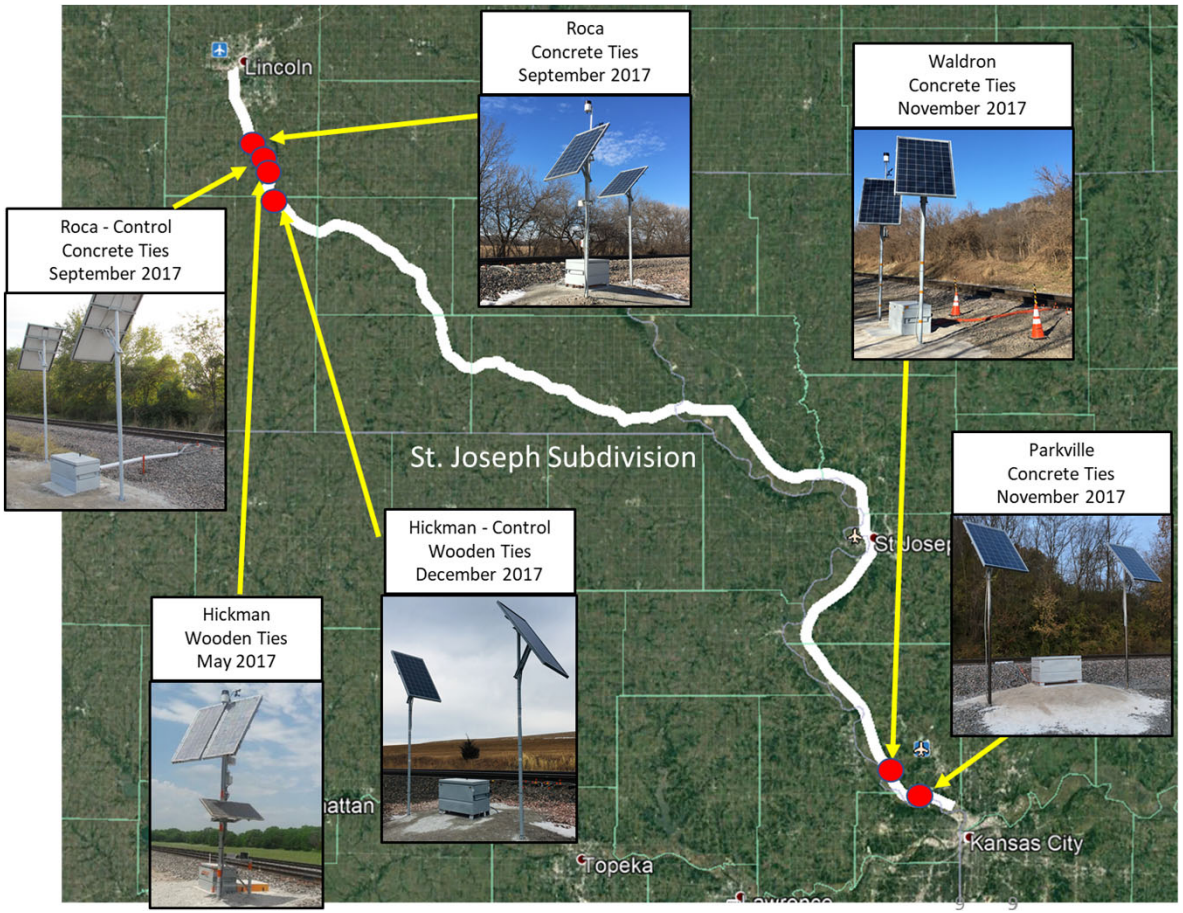
Li et al., 2015





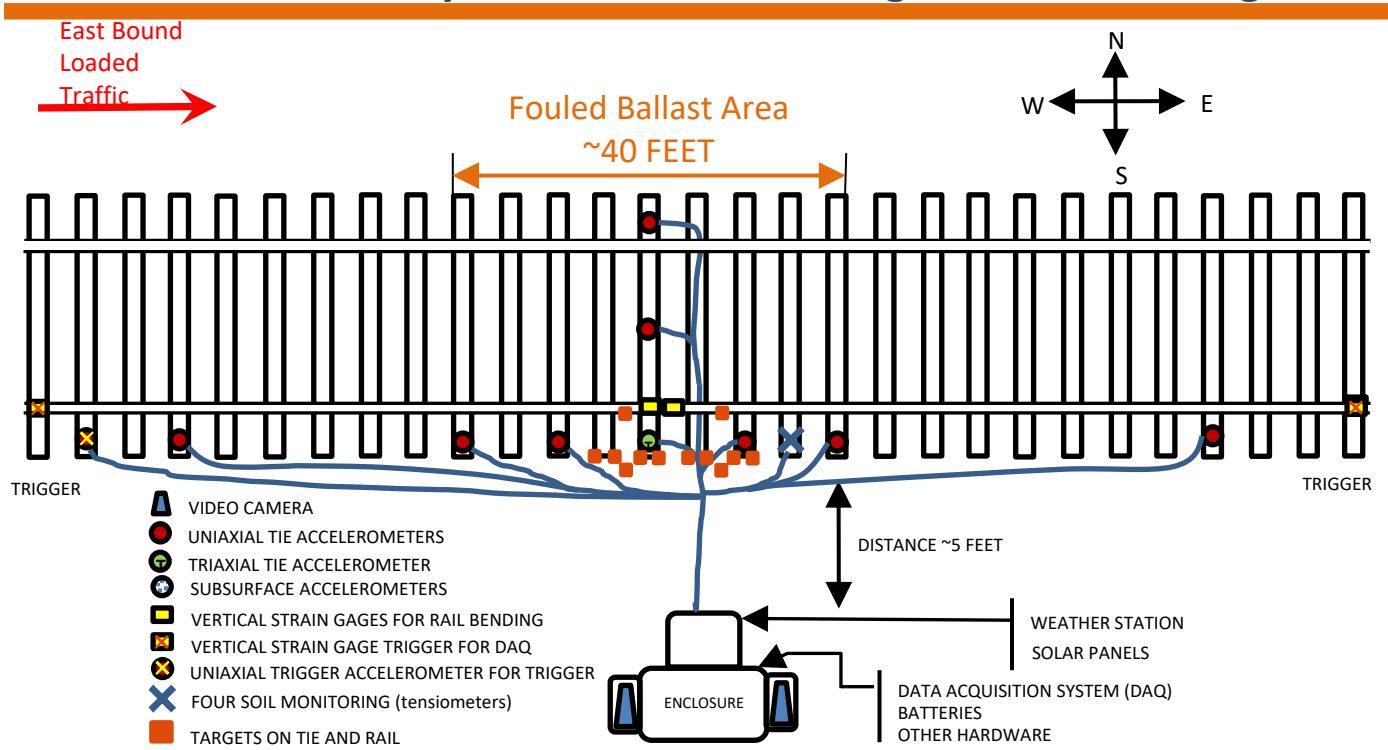
Digital Twin + Analytics = Forecast

Instrumentation Locations – Monitored by UIUC: Tim Stark



- Monitor track for changes during waiver period
- Solar panels and wind generators
- Sites monitor:
  - Daily train loading
  - Support conditions
  - Transient deflections
  - Soil moisture changes
  - Weather patterns
- Insight into mechanisms underlying track geometry changes.

Instrumentation Layout at Timber Tie Long-Term Monitoring Sites



Concrete sites have 10 tie strain gauges

Installed Video Cameras

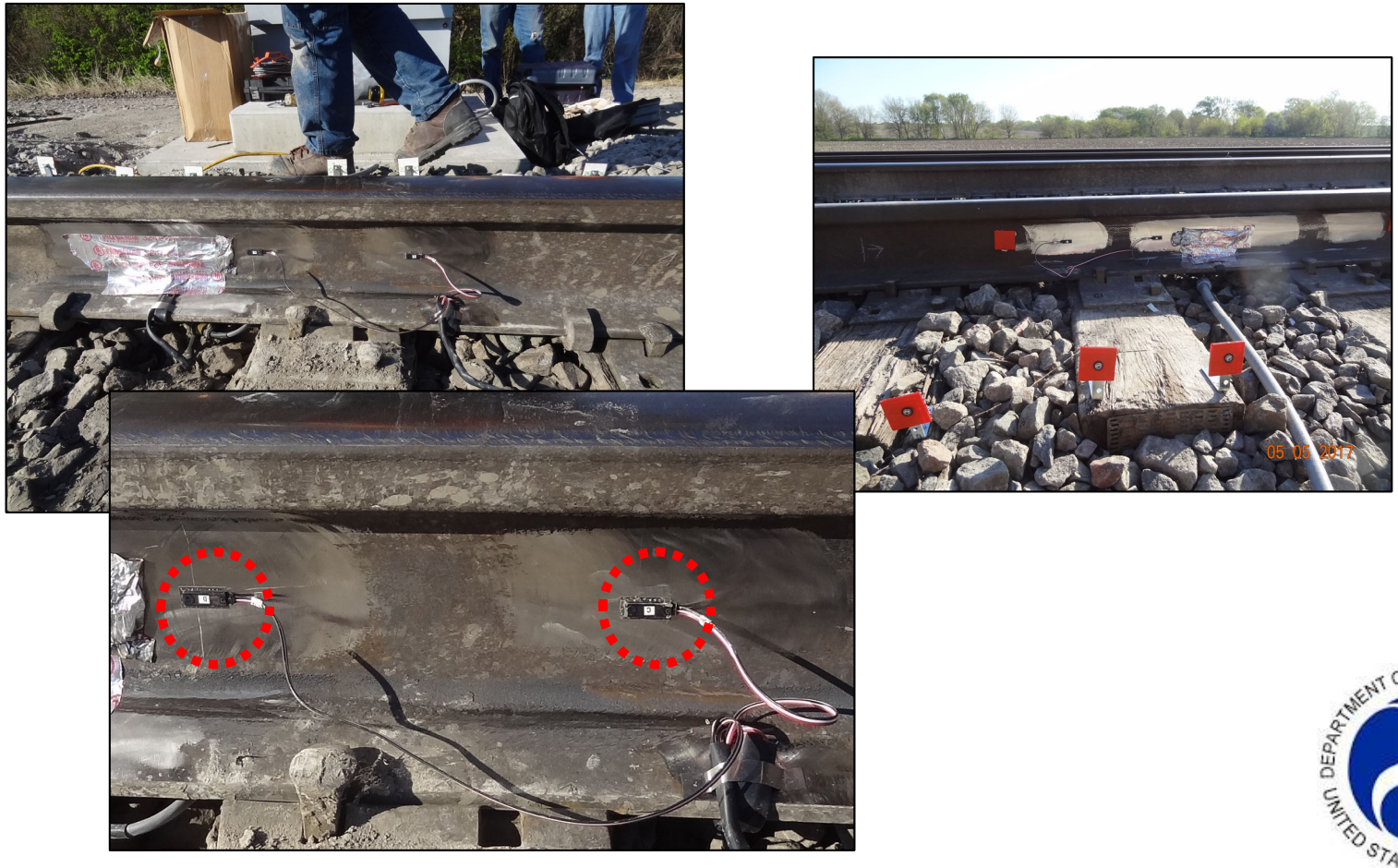
Installed Accelerometers & Targets

Triaxial Accelerometer & Western Targets

Uniaxial Accelerometer

Eastern Targets

Installing Rail Strain Gages



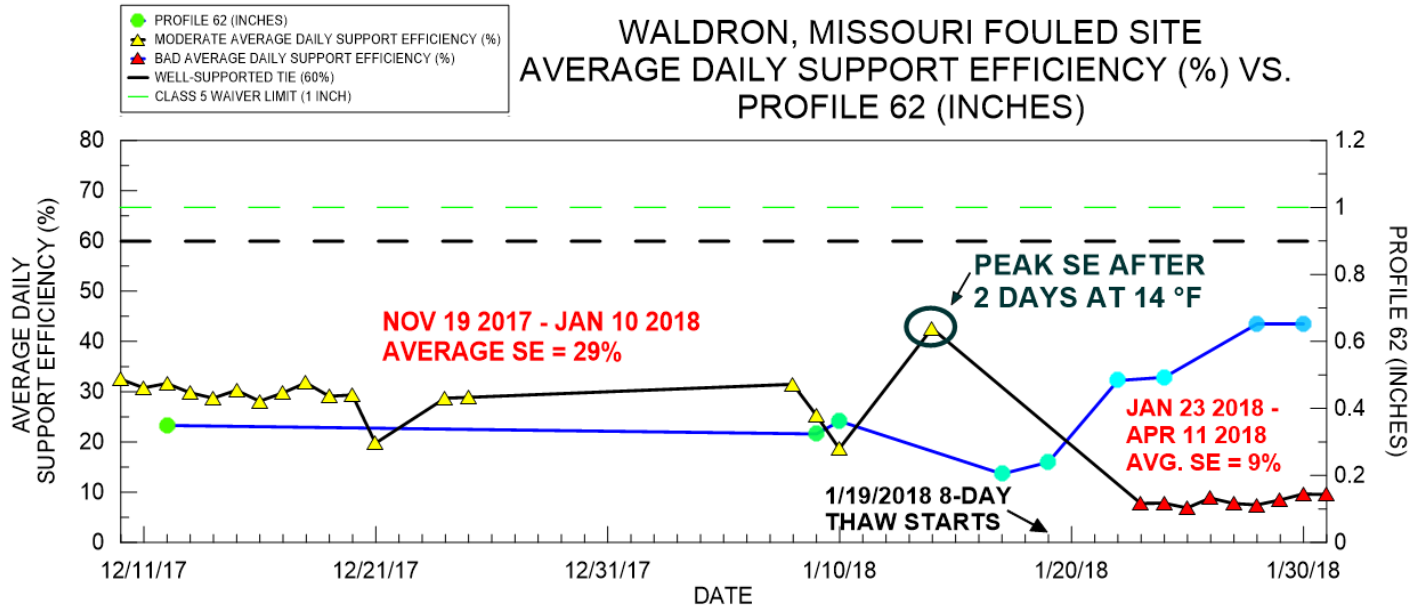
Calibrating Rail Strain Gages

Installing Soil Moisture Probes

Installing Soil Moisture Probes

Effort of Tie Support on Track Geometry

- SE drops from 29% to 9% at Track Profile change
- Difference in tie-ballast gap larger during low SE
- Peak SE @ freezing temp.



Summary of Long-Term Monitoring To Date

- Fouling condition and weather significantly impact track geometry
- Track support changes rapidly and affects track geometry deterioration rates well after change occurred
- Rapid changes in track support highlight the potential for rapid changes in track geometry that have not been observed
- Track load redistribution occurs routinely with fouling and is a focus of future measurements

U.S. Department of Transportation
Federal Railroad Administration

Problem Detection for Ballast

Volpe

Track Support Problems

- Track Load Redistribution
- Ballast Rearrangement
- Track Geometry


Figure courtesy Mario Ruel, CN

Inspection: GPR (Ground Penetrating Radar)

- Clean Ballast Depth, Moisture
- Longitudinal Variations

Tie Bearing Capacity Problems

- Tie and Rail Loads
- Cross Level and Geometry
- Track Position Movement


Figure courtesy FRA

Inspection: Seismic (SASW)

- Resilient Modulus
- Density

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Problem Detection for Subgrade

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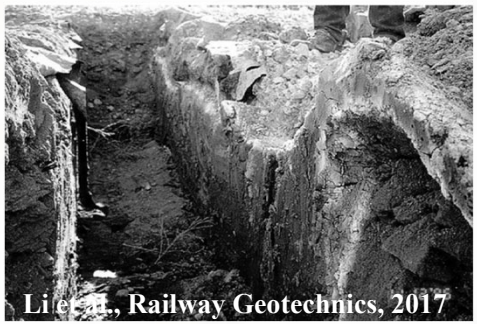
Squeeze/Heave



Li et al., Railway Geotechnics, 2017

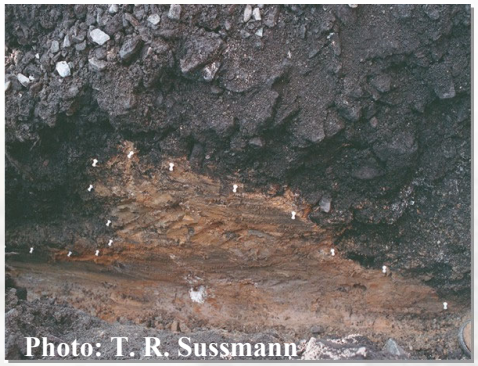


Photo: T. R. Sussmann

Ballast Pockets

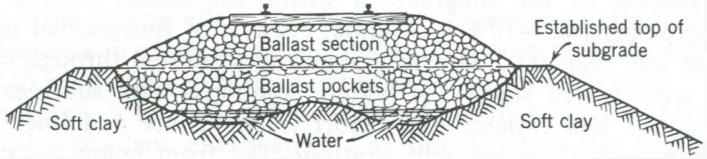


Photo: T. R. Sussmann

Inspection/Quality Control: Strength from Modulus Correlation

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Foundation failure

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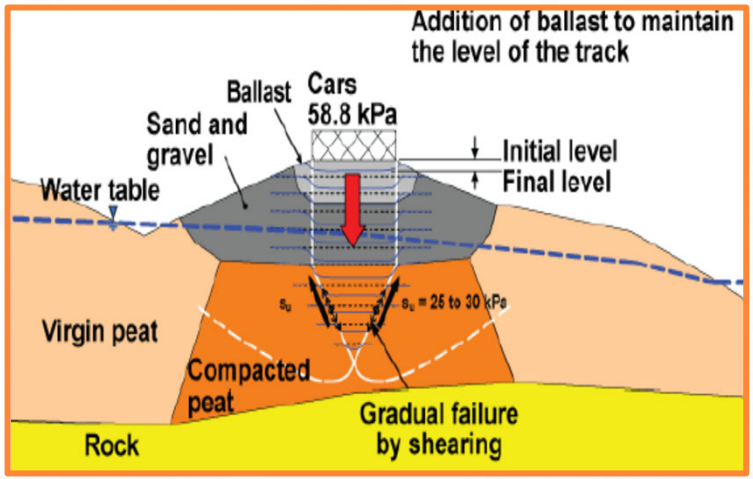

- **Settlement: 30 cm over 8 years**
- **Failure due to sudden and significant settlement**
- **Spurred Canadian research into VTD**

Figures: Canadian Transportation Safety Board Railway Investigation Report: R04Q0040, 2004

The Future: RR 4.0

- Inspection and monitoring technology
  - Detect and quantify safety critical track structure parameters
  - Predict future condition and safe inspection interval
- Analytical solutions from smart sensors
  - Track load redistribution
  - Ballast properties for tie support, settlement rate, and lateral resistance
  - Track load redistribution analysis
- Condition forecasting will require site specific properties

Autonomous Track Geometry Measurement System

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