Mechanistic Investigation of Timber Crosstie Spike Failures

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U.S. Department of Transportation
Federal Railroad Administration

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UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

Acknowledgements

- Project Sponsor

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- Industry Partnership

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Outline

- Timber Crosstie Fastener Terminology
- Introduction to Broken Spikes
- Broken Spike Derailments
- Industry Survey
- Field Visits
- Primary Hypotheses
- Finite Element Modeling
- Laboratory Plan
- Acknowledgements

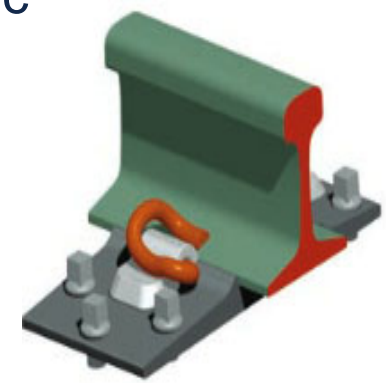
Traditional Fastening Systems

Traditional

Traditional with Curve Blocks

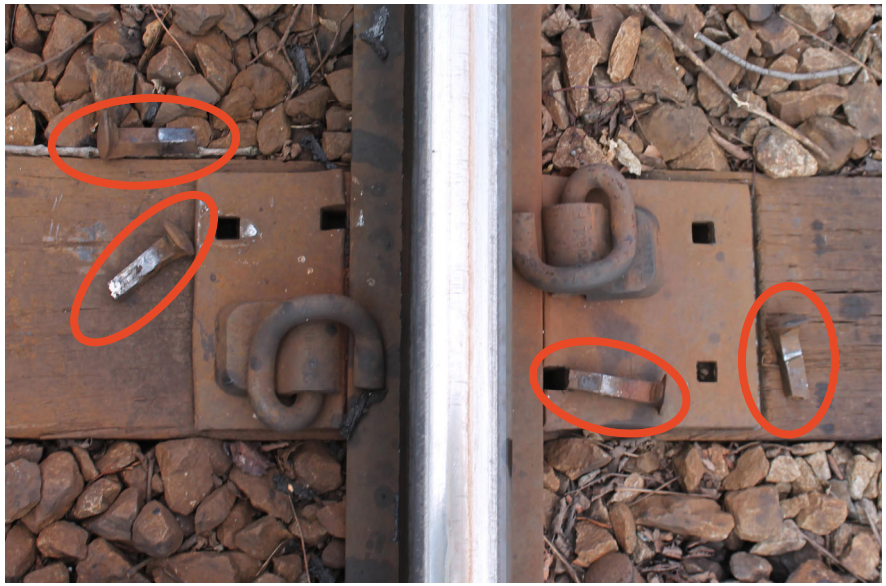
Premium Fastening Systems

- Fasten the rail securely to a timber (or composite) crosstie using an elastic fastener, a tie plate, and spikes
- Multiple varieties:
  - Clip: e-clip, safelok, fastclip, etc.
  - Plate: rolled, cast, Victor, etc.
  - Spikes: cut spikes, screw spikes, lag screws, etc.
- Advantages:
  - Increased rail-rollover restraint
  - Stronger gage-restraint
  - Do not require rail anchors
  - Reduced spike-kill of crossties



Sources: Pandrol, Lewis Nut and Bolt

Challenge: Broken Spikes



Broken Spike Derailments

Fabyan, AB - 2012 (TSB Canada)

Vandergrift, PA - 2014 (Brad Kerchof)

Glacier Park, MT - 2006 (BNSF)

Mosier, OR - 2016 (Sean Aiken)

Industry Survey Overview

- **Objective:** Collect information about the scope of the broken spike problem and data to focus the future phases of the project
- 11 questions
  - 6 multiple-choice questions
  - 5 short-answer questions
- 24 Responses from:

AMTRAK
METROLINK
BNSF RAILWAY
KANSAS CITY SOUTHERN Lines
NS NORFOLK SOUTHERN
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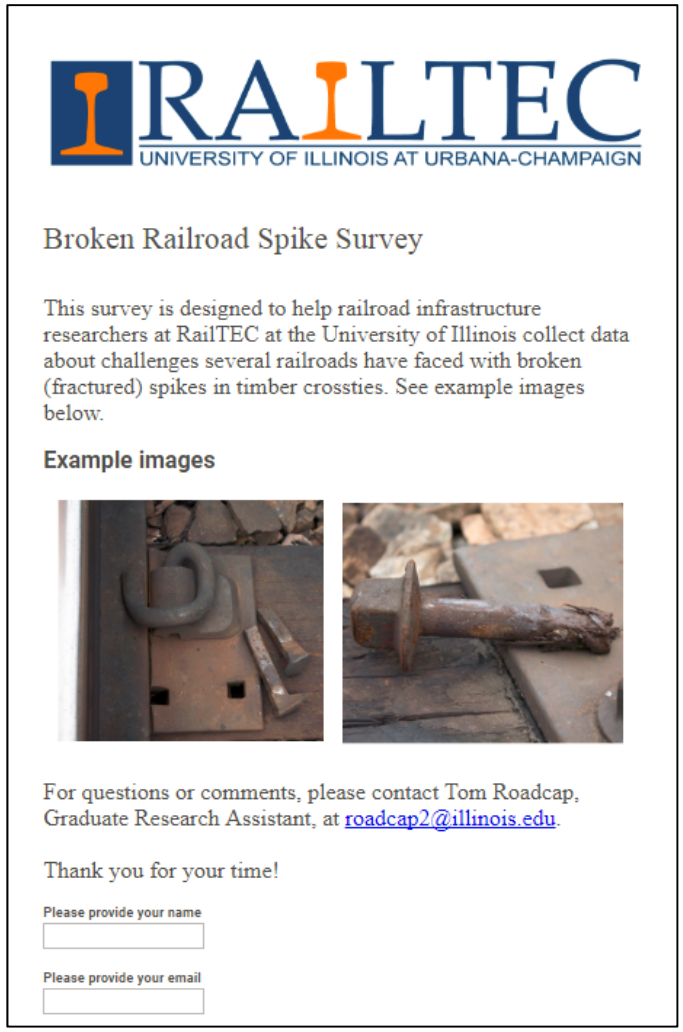

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Broken Railroad Spike Survey

This survey is designed to help railroad infrastructure researchers at RailTEC at the University of Illinois collect data about challenges several railroads have faced with broken (fractured) spikes in timber crossties. See example images below.

Example images

For questions or comments, please contact Tom Roadcap, Graduate Research Assistant, at roadcap2@illinois.edu.

Thank you for your time!

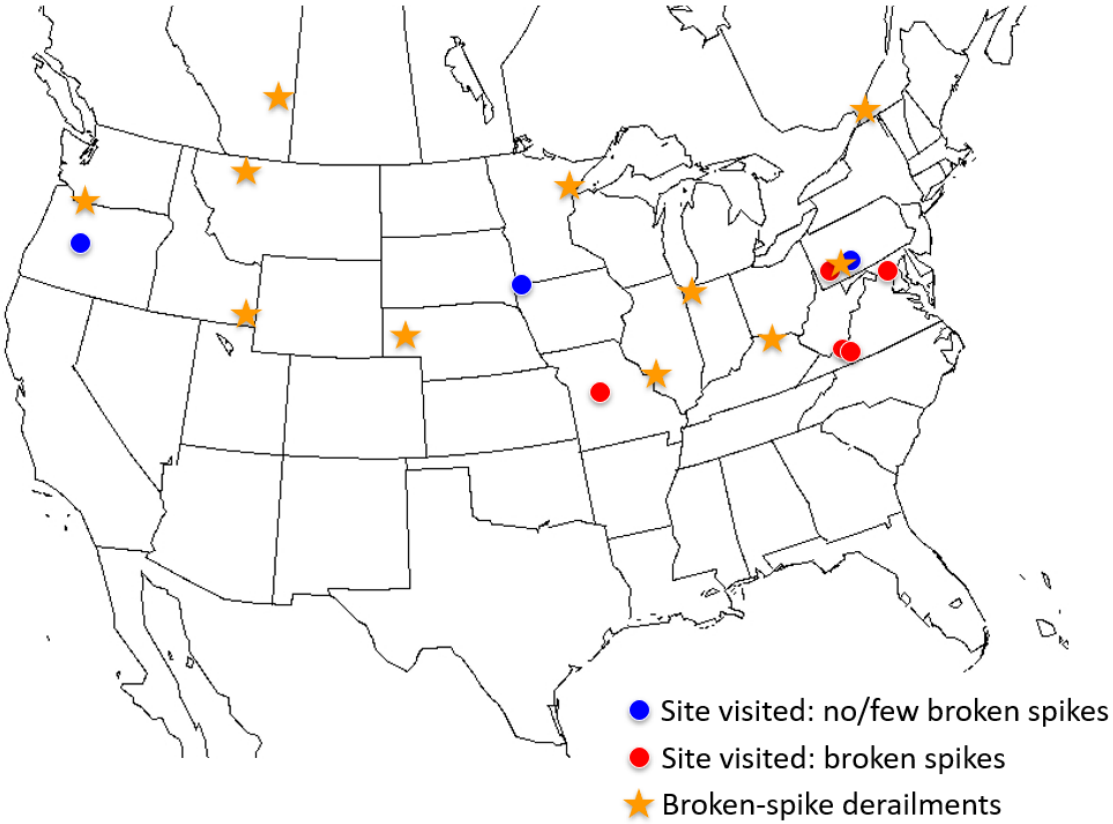
Please provide your name

Please provide your email

High-Level Results

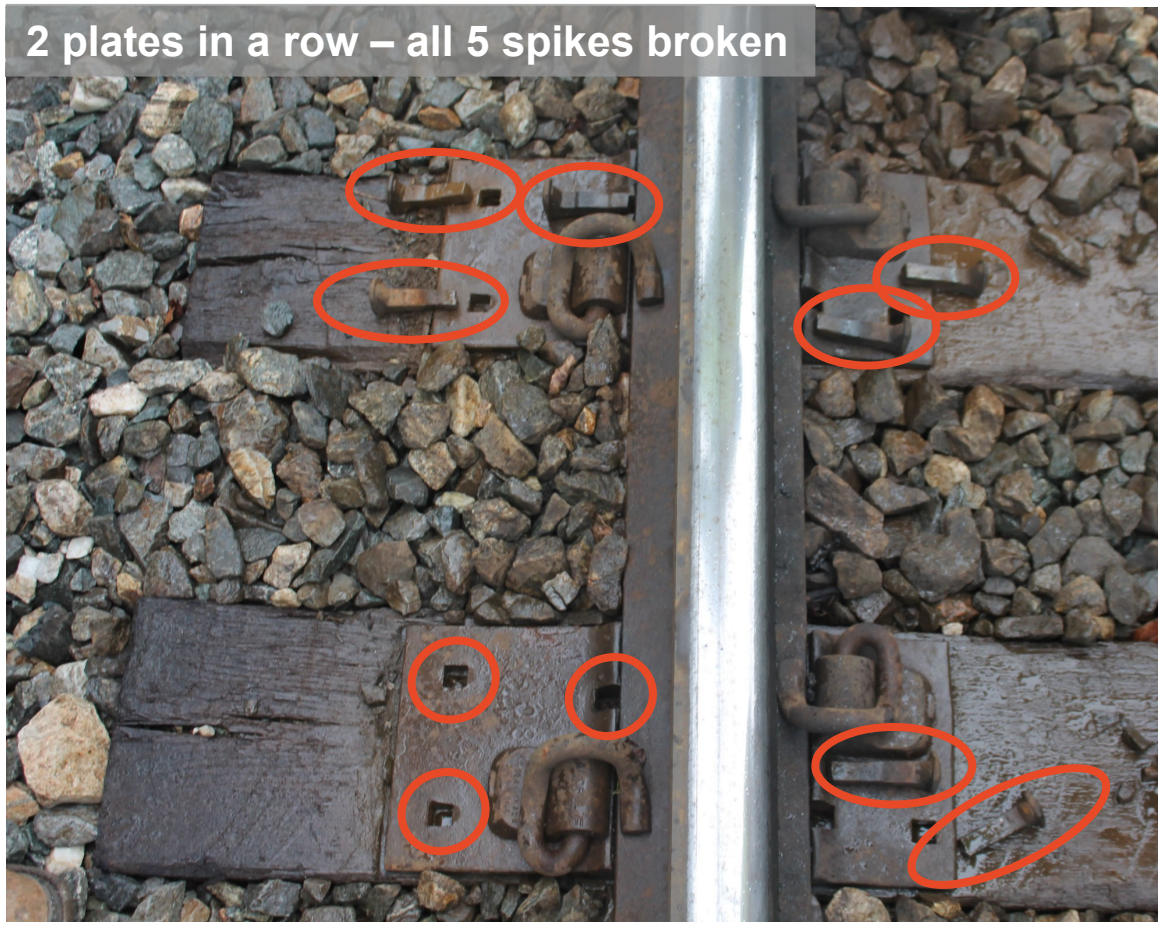
- 8 out of 9 agencies reported broken spike problems
- All railroads:
  - Identified tight curves and new ties as major problem areas
  - Saw rapid gage deterioration and inspection challenges as key concerns
- Most railroads:
  - Saw broken spikes partially or primarily in premium systems
  - Saw breakage as a moderate to serious problem
  - Did not identify a strong seasonal correlation with spike breakage
- One railroad:
  - Does not have many premium fasteners installed on the system
  - Saw the problem as a relatively small one
  - Has wintertime GRMS testing to locate broken spikes
  - Has long-standing experience with the issue

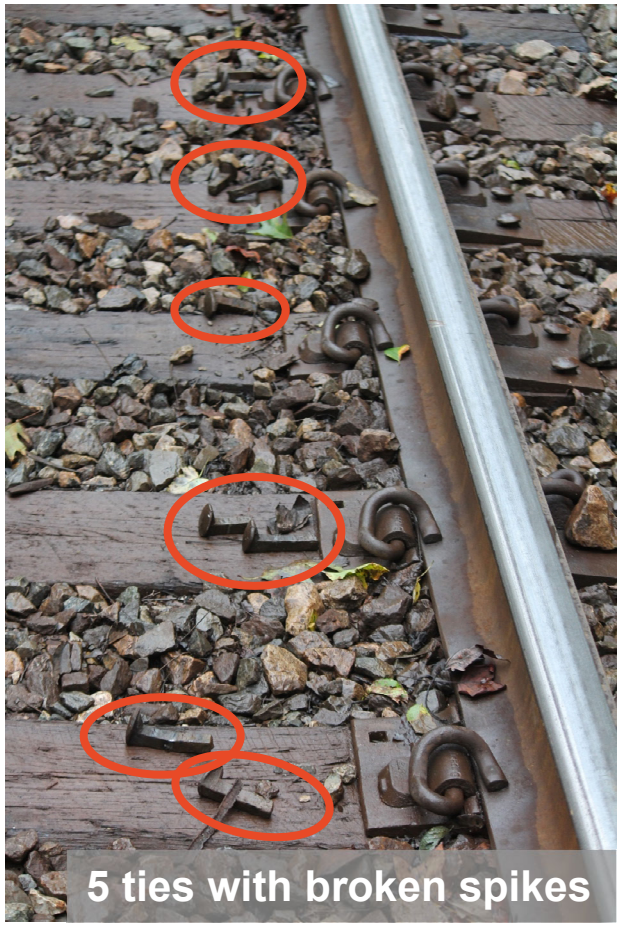
Field Visits and Derailment Locations



- Objectives:
  - Visit locations with various types of fasteners and spikes/screws, grades, curvature, railroad company, traffic and tonnage, etc.
  - Collect data about magnitude of spike failure problems, failure locations, maintenance practices surrounding broken spikes, etc.

Severe Broken Spike Clusters





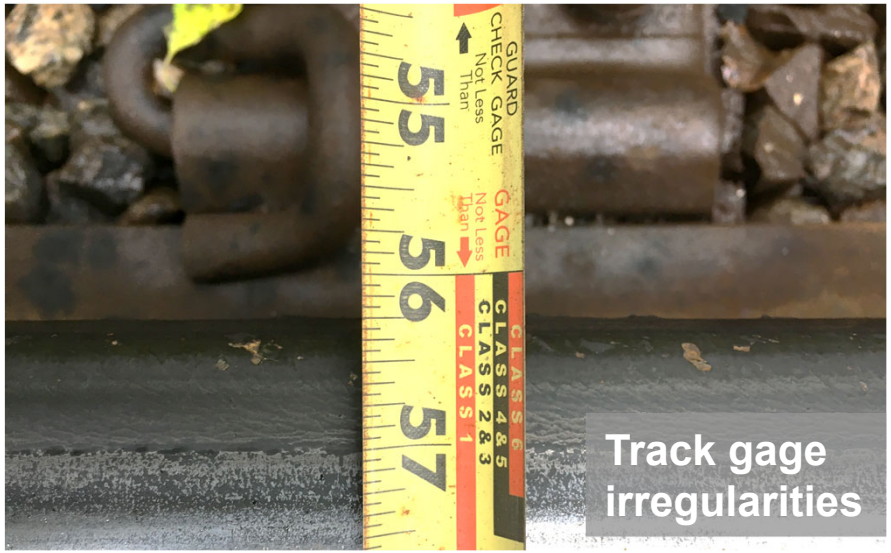
- One curve inspected had 121 broken spikes within 150 ties on the high rail; 23% of cut spikes were broken.

Anatomy of a Broken Spike Cluster

False-flange on low rail

Lubricant build-up

Regular interval of spike breakage



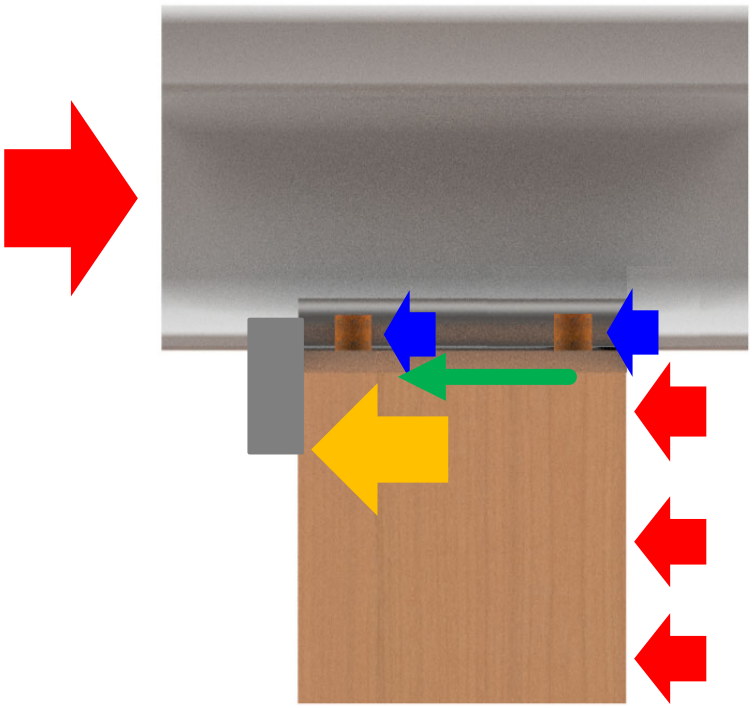
Track gage irregularities

Summary of Field Visits

- Spikes typically break in premium fasteners as opposed to traditional fastening system
- Some broken spikes found individually, others found in clusters of broken spikes
- Gage irregularity, curve grease build-up, and false-flange wear often found around clusters of broken spikes.
- Often found in new ties, but sometimes in older ties as well
- Mainly found in curves, also sometimes in special trackwork
- Often see spike breakage repeatedly in the same curves and even the same spike holes
- Inspection for broken spikes is time and labor intensive: requires walking curve, tapping on each spike head
- Temperature affects how easily broken spikes are identified and removed
- Screw spikes generally harder to remove than cut spikes

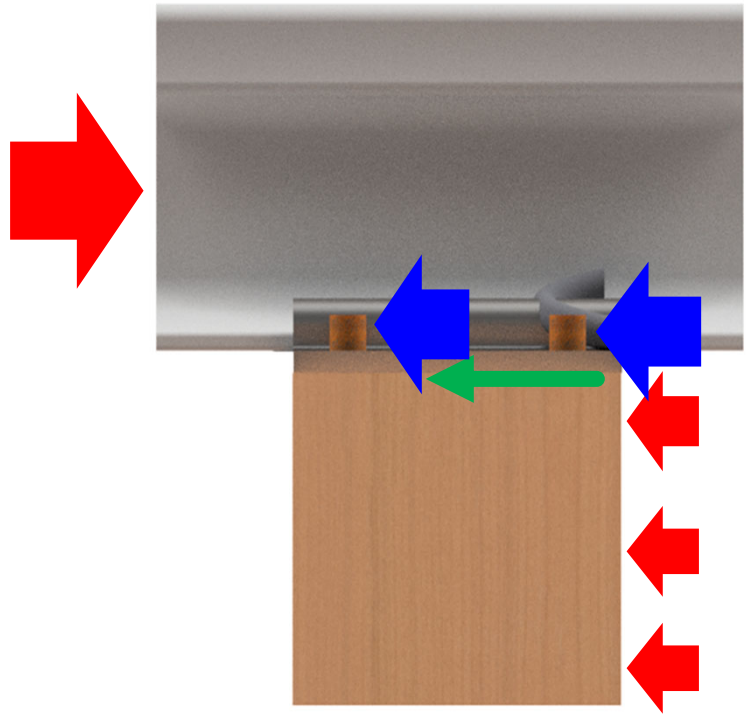
Potential Driving Factor: Longitudinal Load

- The effect of no rail anchor and elastic fastener: higher spike stress



$F_{Rail\text{-}Tie} =$

$F_{Anchor} + F_{Spikes} + F_{Plate\text{-}Tie\ Friction}$



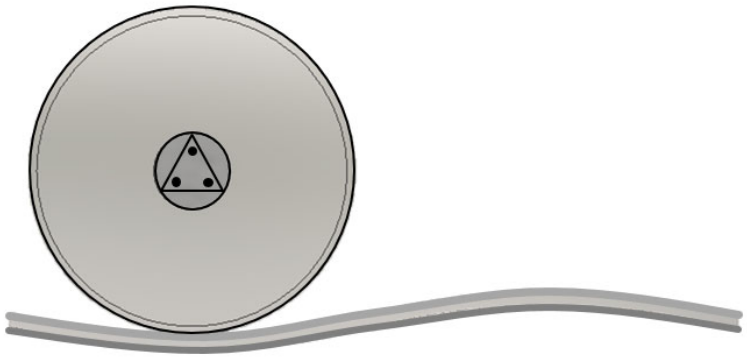
$F_{Rail\text{-}Tie} =$

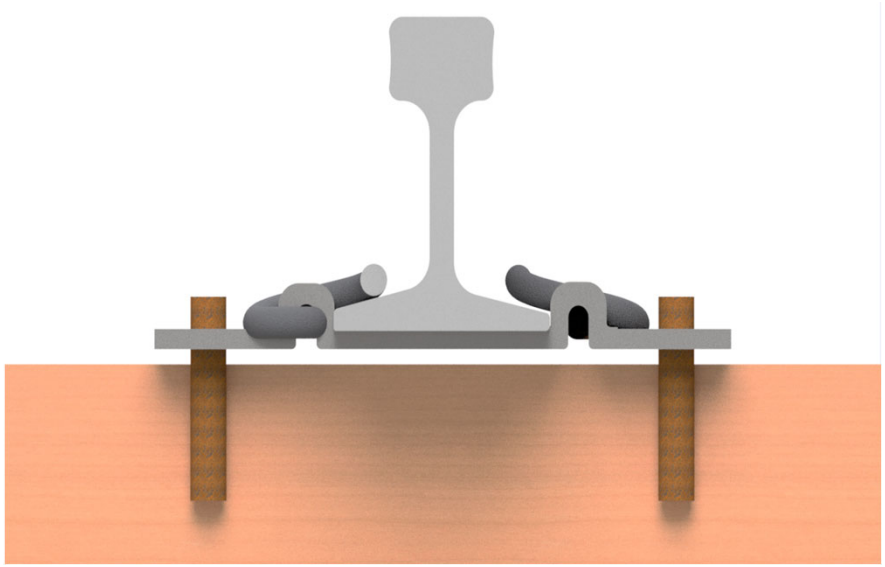
$F_{Spikes} + F_{Plate\text{-}Tie\ Friction}$

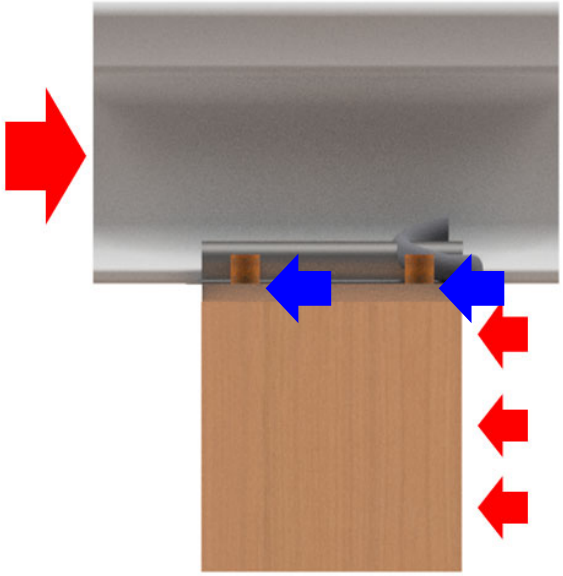
Evidence of High Longitudinal Forces

Compounding Factor: Rail Uplift

- Rail uplift reduces or eliminates plate-crosstie friction







$F_{Rail\text{-}Tie} = F_{Spikes}$

Video 1: Uplift in a Premium System

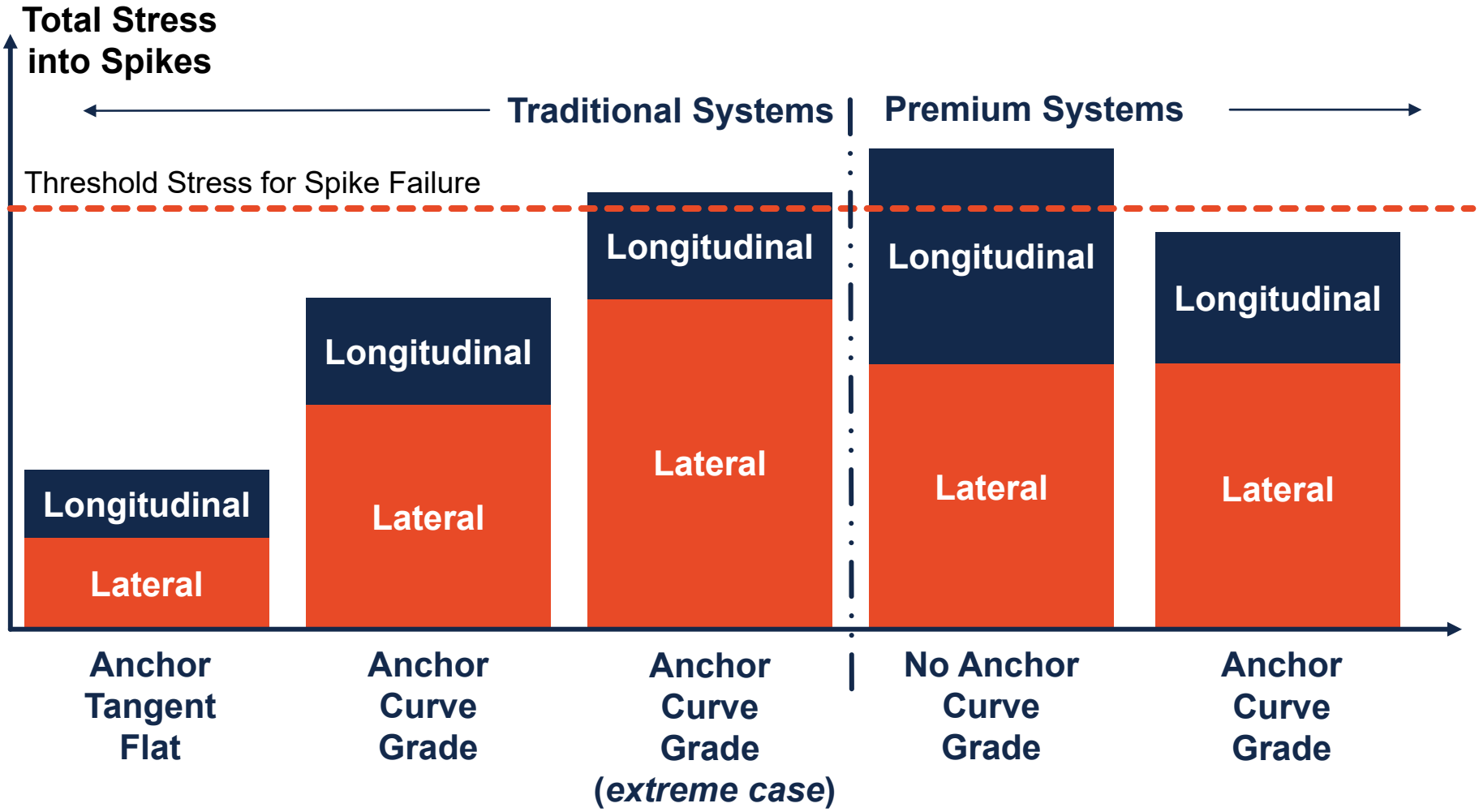
Video 2: Uplift in a Premium System

No Uplift in a Traditional System

Potential Driving Factor: Lateral and Longitudinal Stiffness

- Key idea: stiff fastening system spreads load over fewer ties
- Lateral direction
  - Premium systems allow less rail head deflection than traditional systems
  - This results in rail movement being confined to fewer ties, possibly meaning that fewer ties are engaged to counteract lateral force
  - With fewer ties taking load, spikes in loaded ties have to take more stress
- Longitudinal Direction
  - Track with traditional plates and anchors:
    - Some longitudinal rail movement allowed
    - More ties absorb longitudinal load (low longitudinal stiffness)
    - Lower fastener-to-tie forces on an individual tie
  - Track with premium fasteners:
    - Little longitudinal rail movement due to clamping force
    - Fewer ties can absorb longitudinal load (high longitudinal stiffness)
    - Higher fastener-to-tie forces on an individual tie (= spike breakage)

Stress in Spikes – Hypothetical Graph



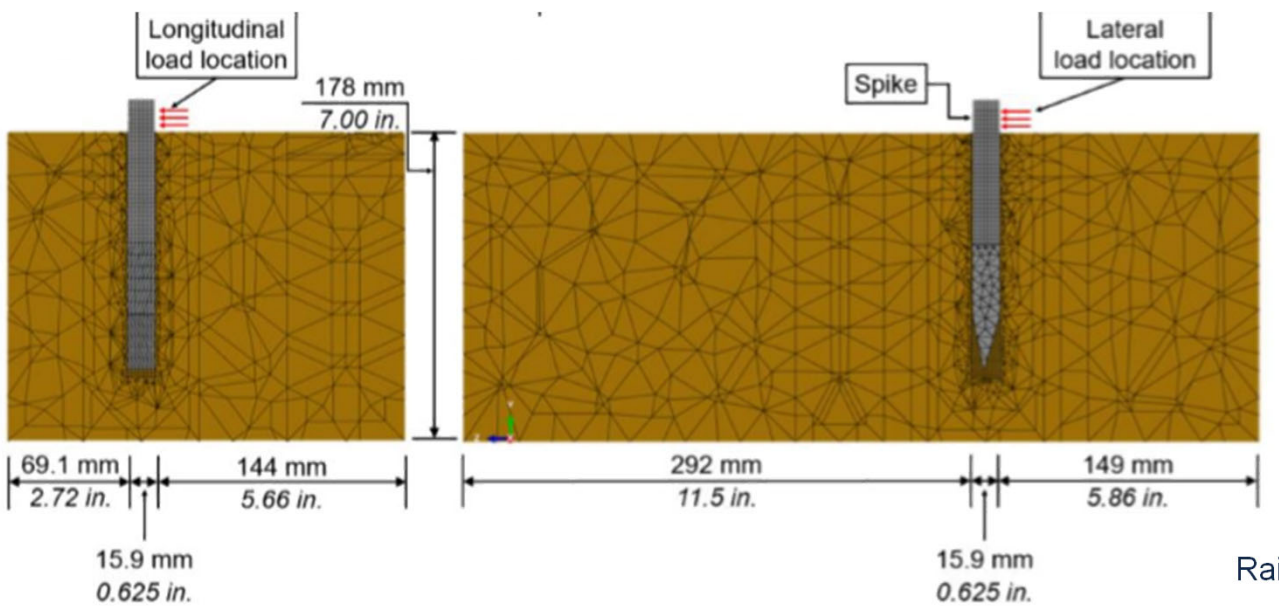




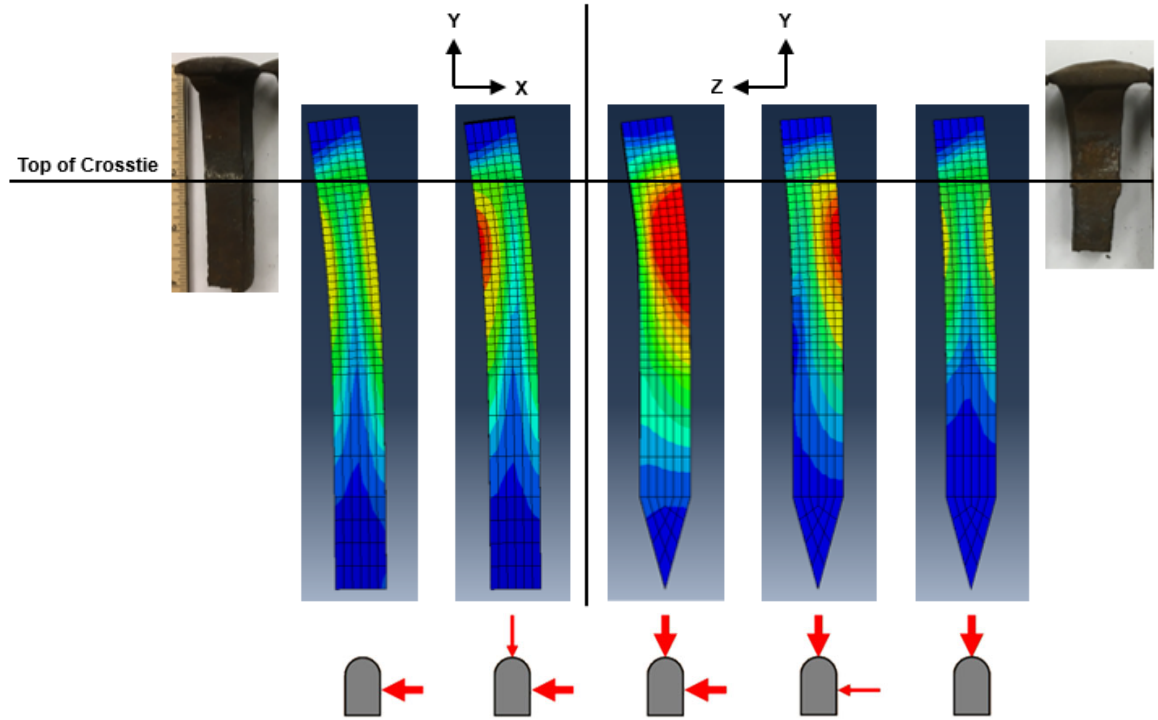
Finite Element Modeling

Understanding spike performance

- Model includes several types hardwoods and includes timber anisotropy
- Spikes modeled according to AREMA and railroad specifications
- Spike perfectly vertical and square with tie plate/tie
- Multiple load cases in both lateral and longitudinal directions, with plate-to-spike loads ranging from 0 to 5,000 lbs (22.2 kN)



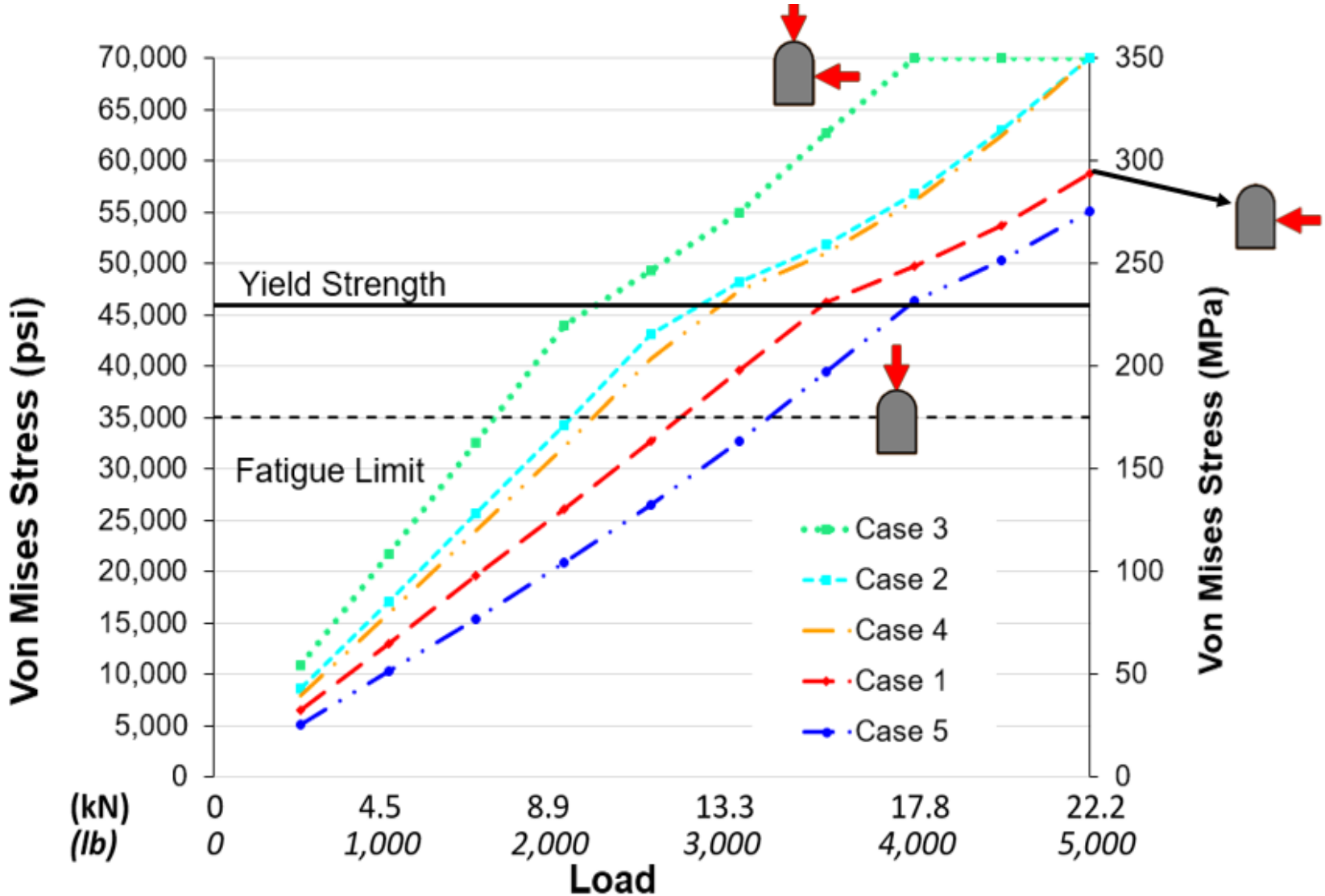
Qualitative Modeling Results



Load Case		1	2	3	4	5
Depth to Maximum Von Mises Stress	mm (*in.*)	27.9 (*1.1*)	20.3 (*0.8*)	20.3 (*0.8*)	17.8 (*0.7*)	17.8 (*0.7*)
Longitudinal Load	kN	22.2	22.2	22.2	11.1	0
	lb	*5,000*	*5,000*	*5,000*	*2,500*	*0*
Lateral Load	kN	0	11.1	22.2	22.2	22.2
	lb	*0*	*2,500*	*5,000*	*5,000*	*5,000*

- Stress concentrates at corner with application of lateral and longitudinal load
  - Representative of failure location in field

Modeling Results



- Max stress is ~20% greater with longitudinal load application than lateral load

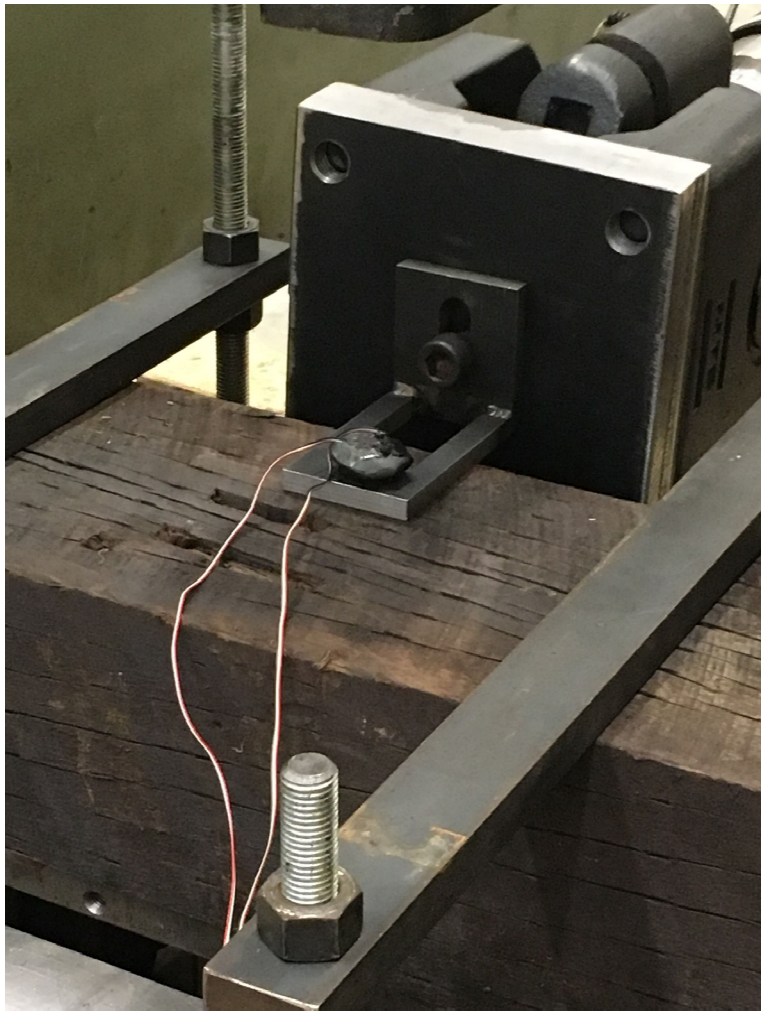
Preliminary Model Findings

- Longitudinal loads are more detrimental to the spike than an equivalent lateral load
  - This is due to the direction of the timber grain
  - This supports the theory that longitudinal loads can drive spike failures
- Stress can exceed spike steel fatigue limit at regular service loads
- Depth of maximum stress dependent on magnitude load
  - More work is needed to quantify factors affecting max stress depth
- Timber species does not have a major impact on spike stress or depth of maximum stress as modeled
- Future laboratory work will be used to validate model findings as well as test hypotheses

Laboratory Investigation

Understanding Fastener Mechanics

- FEM Validation
- Single system longitudinal load test
- Full-scale track tests



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Rail Transportation and Engineering Center (RailTEC)

U.S. Department of Transportation
Federal Railroad Administration

NURail Center

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