Mechanistic Investigation of Timber Crosstie Spike Failures

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Federal Railroad Administration

RAILTEC
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Acknowledgements

- Project Sponsor:

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- Industry Partnership:

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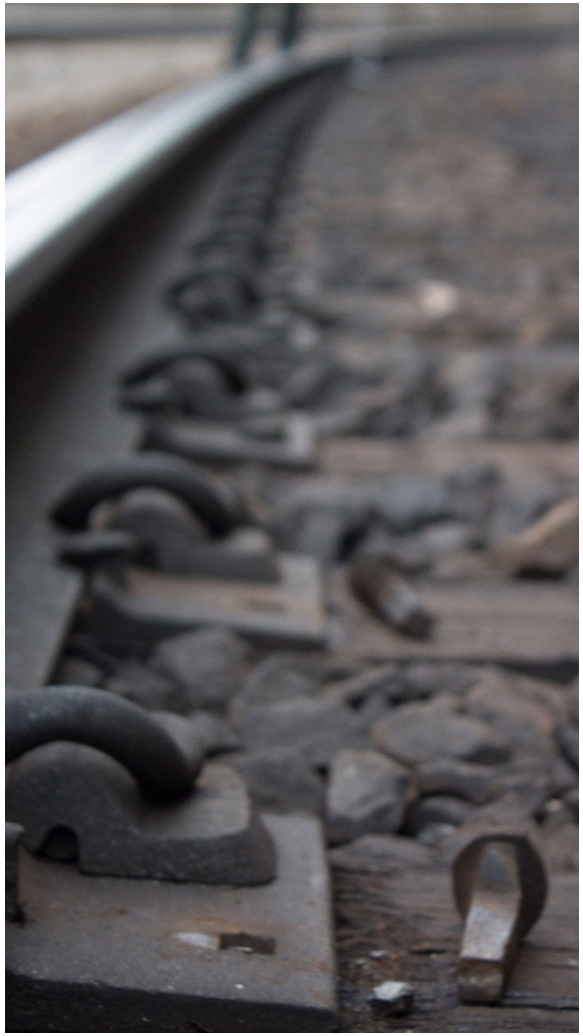
Project Overview

- **PHASE I:** How large is the problem?
  - Industry Survey
  - Interviews and Site Visits
  - Document scope of the problem
  - Hypotheses about spike breakage

- **PHASE II:** What is causing spike failures?
  - Execute laboratory experimentation plan developed in PHASE I
  - Attempt to replicate failures in the laboratory
  - Develop and perform parametric analyses with FE models of fastening systems
  - Validate models with laboratory work

- **PHASE III:** How do we prevent the failures?
  - Perform additional lab tests/FEA as needed
  - Investigate design improvements
  - Recommend improvements



Types of Fastening Systems

Traditional
or
Conventional

Premium
or
Elastic

Challenges: Broken Spikes

- Spike failures are not limited to a particular type of elastic fastener or spike

Broken Spike Derailments


Fabyan, AB - 2012 (TSB Canada)


Vandergrift, PA - 2014 (Brad Kerchof)


Mosier, OR - 2016 (Sean Aiken)

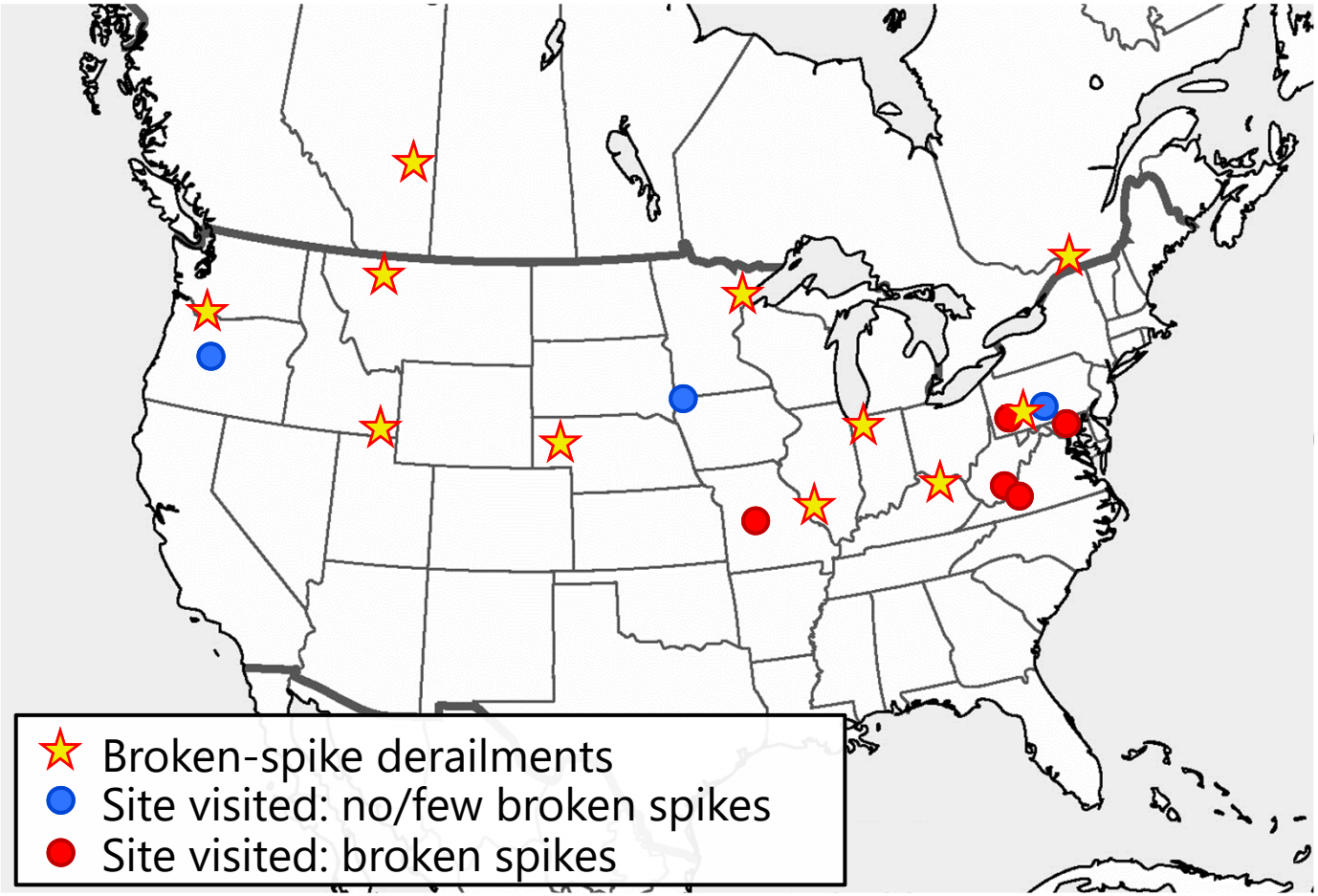

Glacier Park, MT - 2006 (BNSF)

- 11 derailments since 2000
- All track sections had complied with regulatory requirements

Industry Survey Overview

- **Survey Objective:** Collect information about the scope of the broken spike problem and data to focus the future phases of the project
- 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 long-standing experience with the issue
  - Has wintertime GRMS testing to locate broken spikes

Field Visits and Derailment Locations



- Collect data about the characteristics of locations with and without broken spikes and maintenance practices
- Visited various railroad companies, using different fasteners

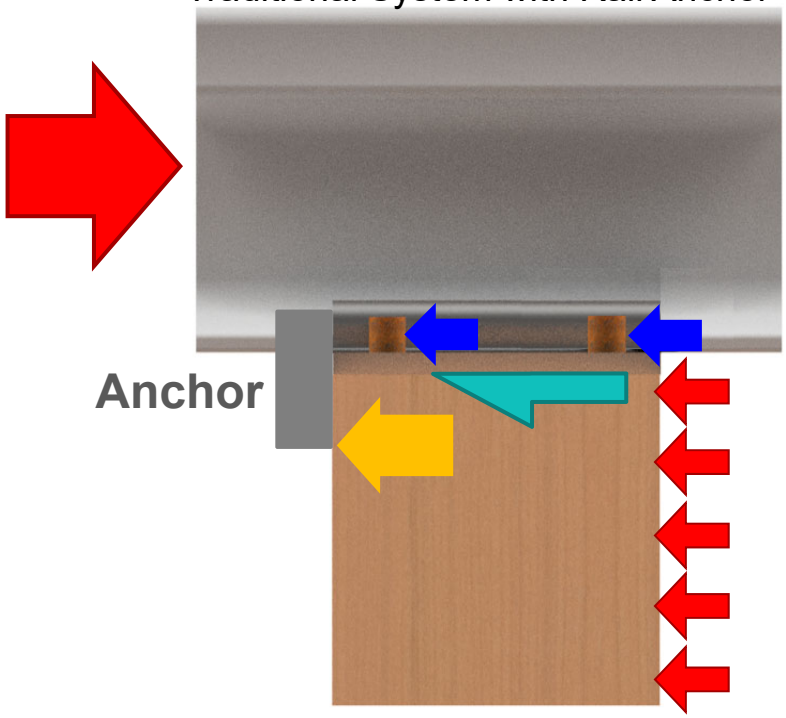
Summary of Field Visits

- Broken spikes were found:
  - Primarily on **premium fastening system**
  - Often **new ties**
  - Mainly on **curves**, but also in **special trackwork**
- Often in the same curves and even the same spike holes
- Broken spikes found both individually and in clusters
- Gage irregularity, curve grease build-up, and false-flange wear often found around clusters of broken spikes
- Identifying broken spikes is time and labor intensive
  - Temperature affects how easily they are identified
  - 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

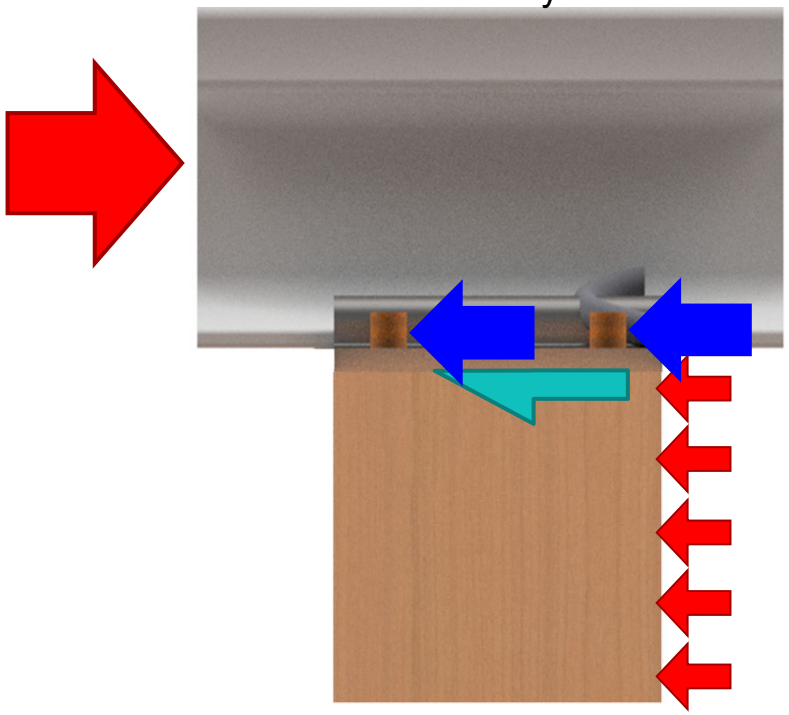
Traditional System with Rail Anchor



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

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

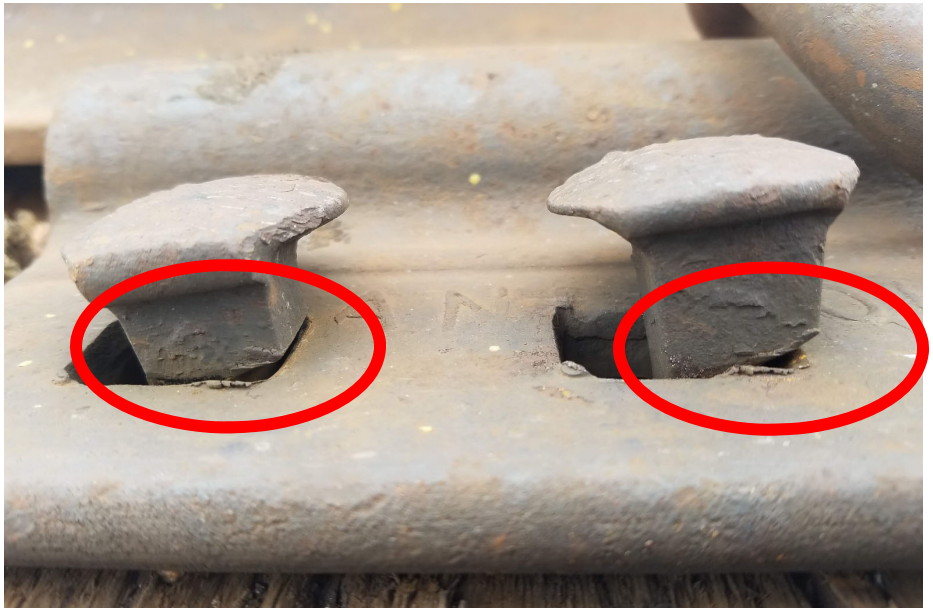
Premium System



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

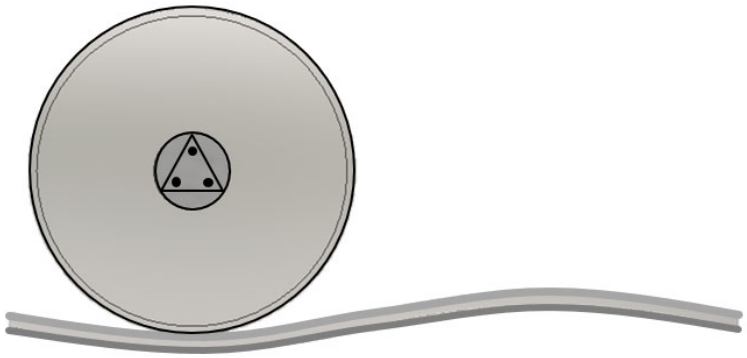
$F_{Spikes} + F_{Plate\text{-}Tie\ Friction}$

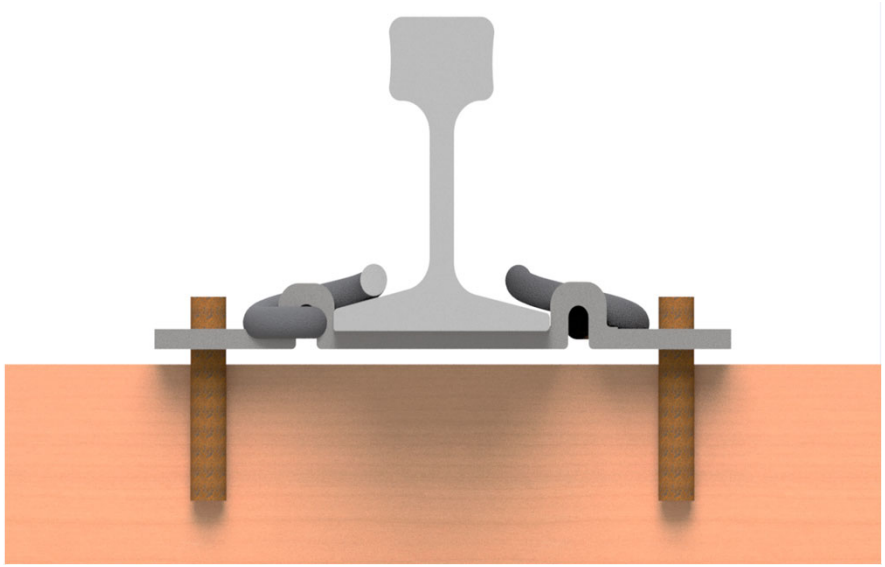
Evidence of High Longitudinal Forces

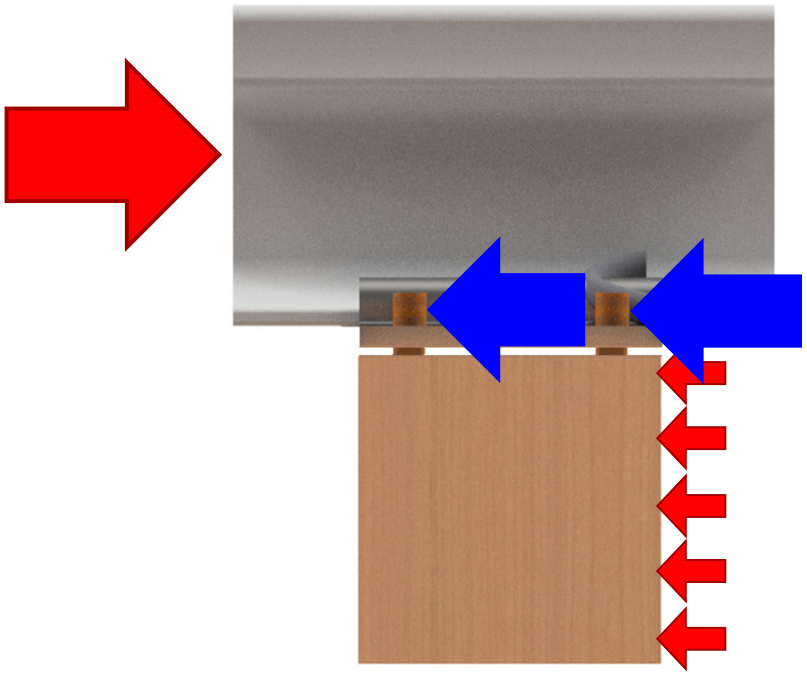


Compounding Factor: Rail Uplift

- Rail uplift reduces or eliminates plate-crosstie friction







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

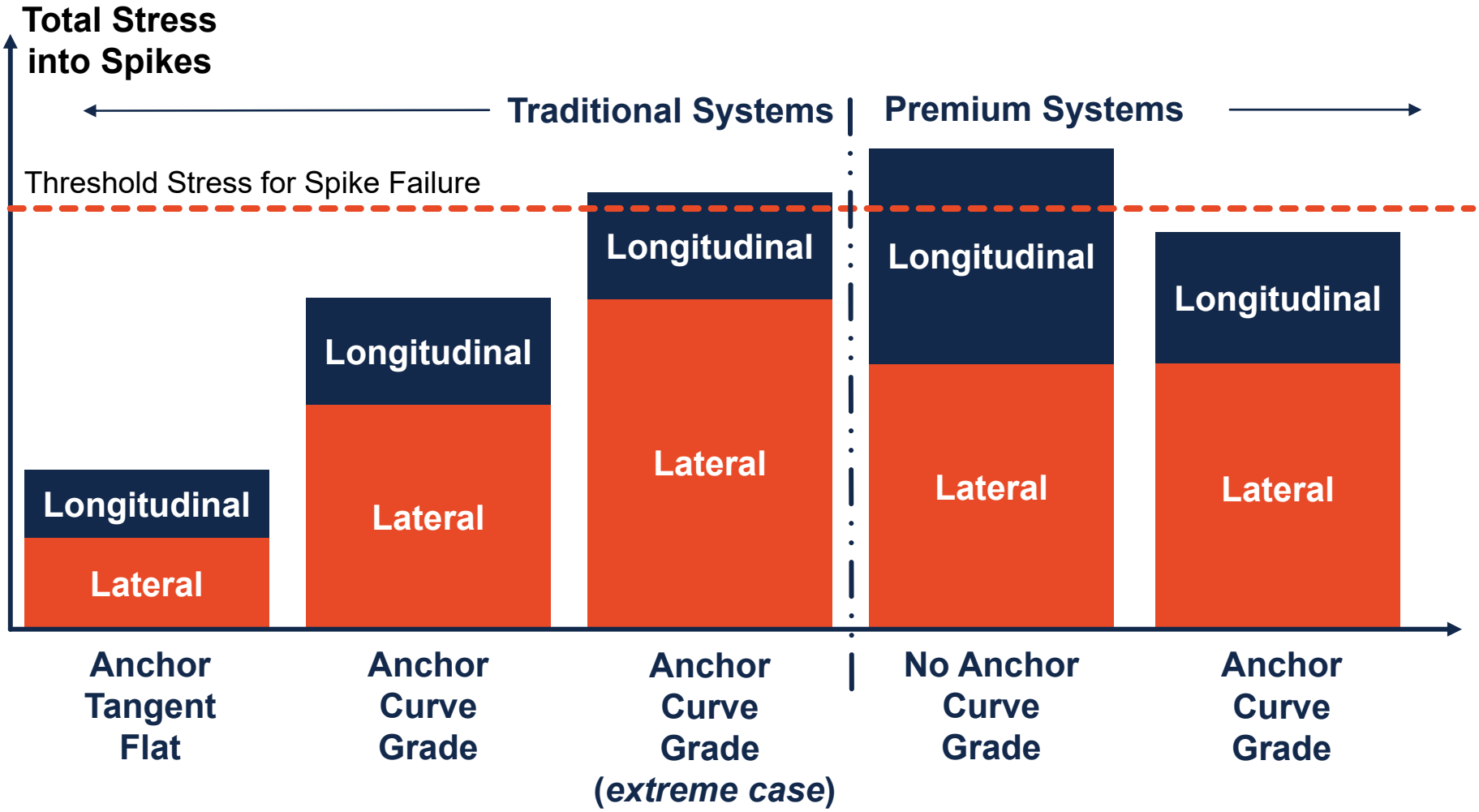
Video 1: Uplift in a Premium System

Video 2: No Uplift in a Traditional System

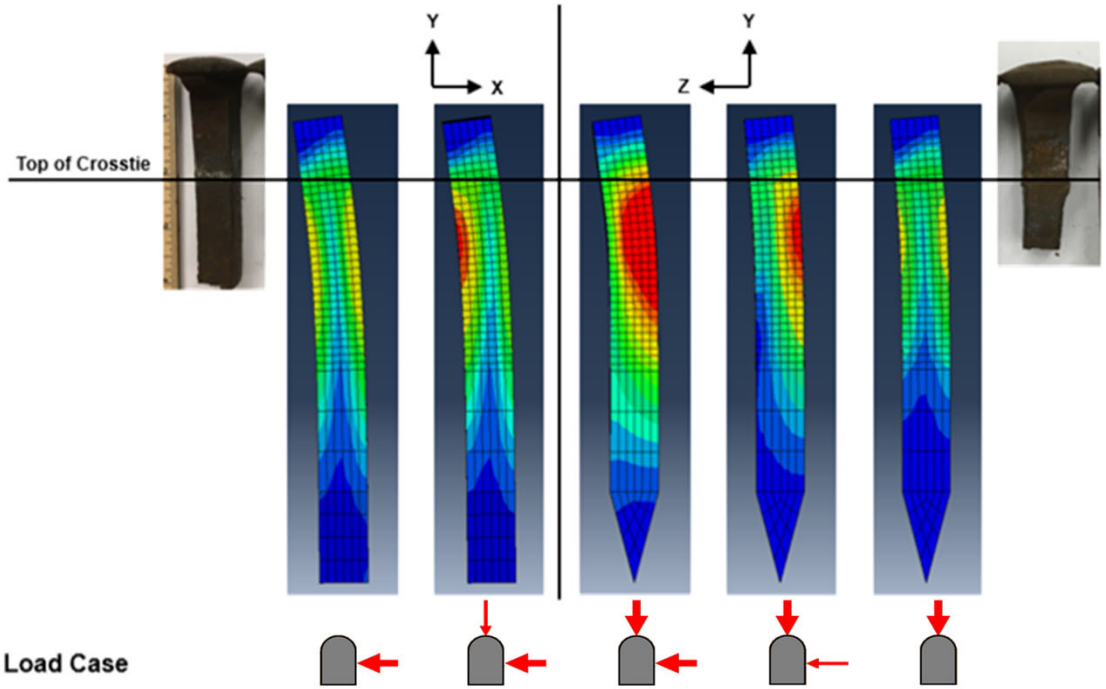
Potential Driving Factor: Lateral and Longitudinal Stiffness

- **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
  - 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)
    - <u>Lower fastener-to-tie forces</u> 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)
    - <u>Higher fastener-to-tie forces</u> on an individual tie (= spike breakage)

Stress in Spikes – Hypothetical Graph



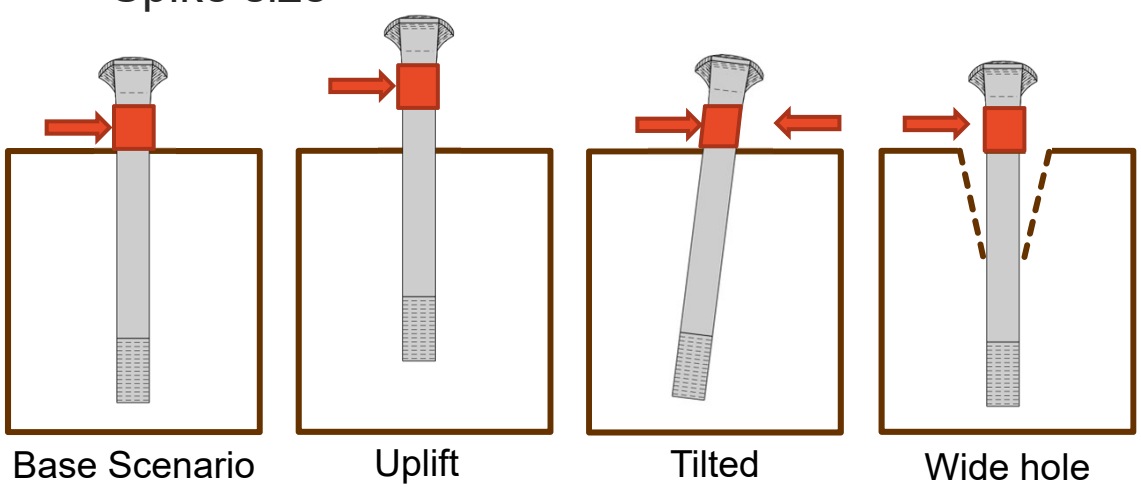
Initial Finite Element Model

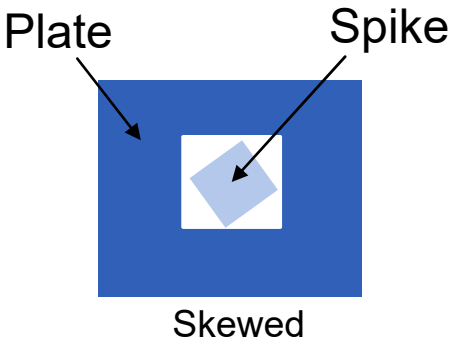


- Longitudinal load is more detrimental than an equivalent lateral load
  - This is due to the timber being less resistant on that direction
  - This finding supports the theory that spike failures in premium fastening systems are primarily related to longitudinal loads
- Stress can exceed the fatigue limit of spike steel at regular service loads
- Max. stress depth varies with the magnitude and direction of applied load

Phase II Finite Element Model

- Improve upon basic model developed in Phase I
  - Calibrate and validate model with laboratory data
  - Incorporate anisotropic behavior beyond timber yield with subroutines
- Potential variables to investigate
  - Timber and steel properties
  - Fastening system clamping force
  - Spike hole shape/condition
  - Spike skew
  - Spike placement within fastening system
  - Spike size

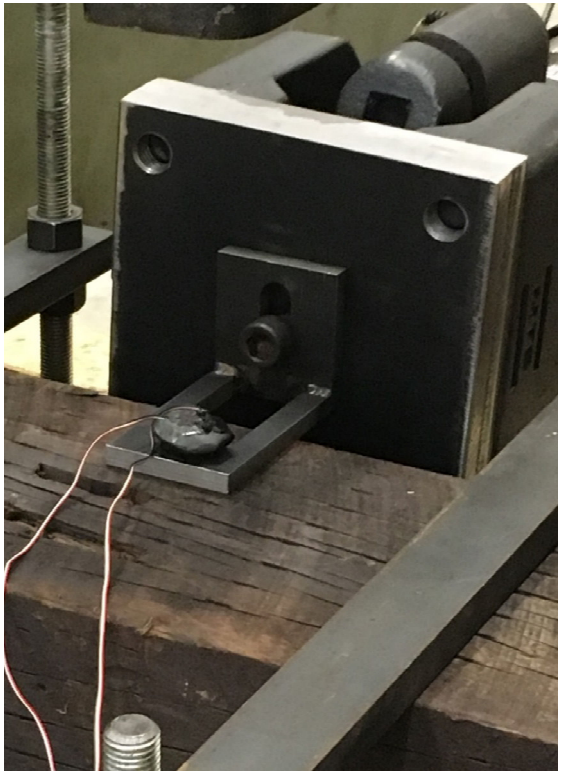




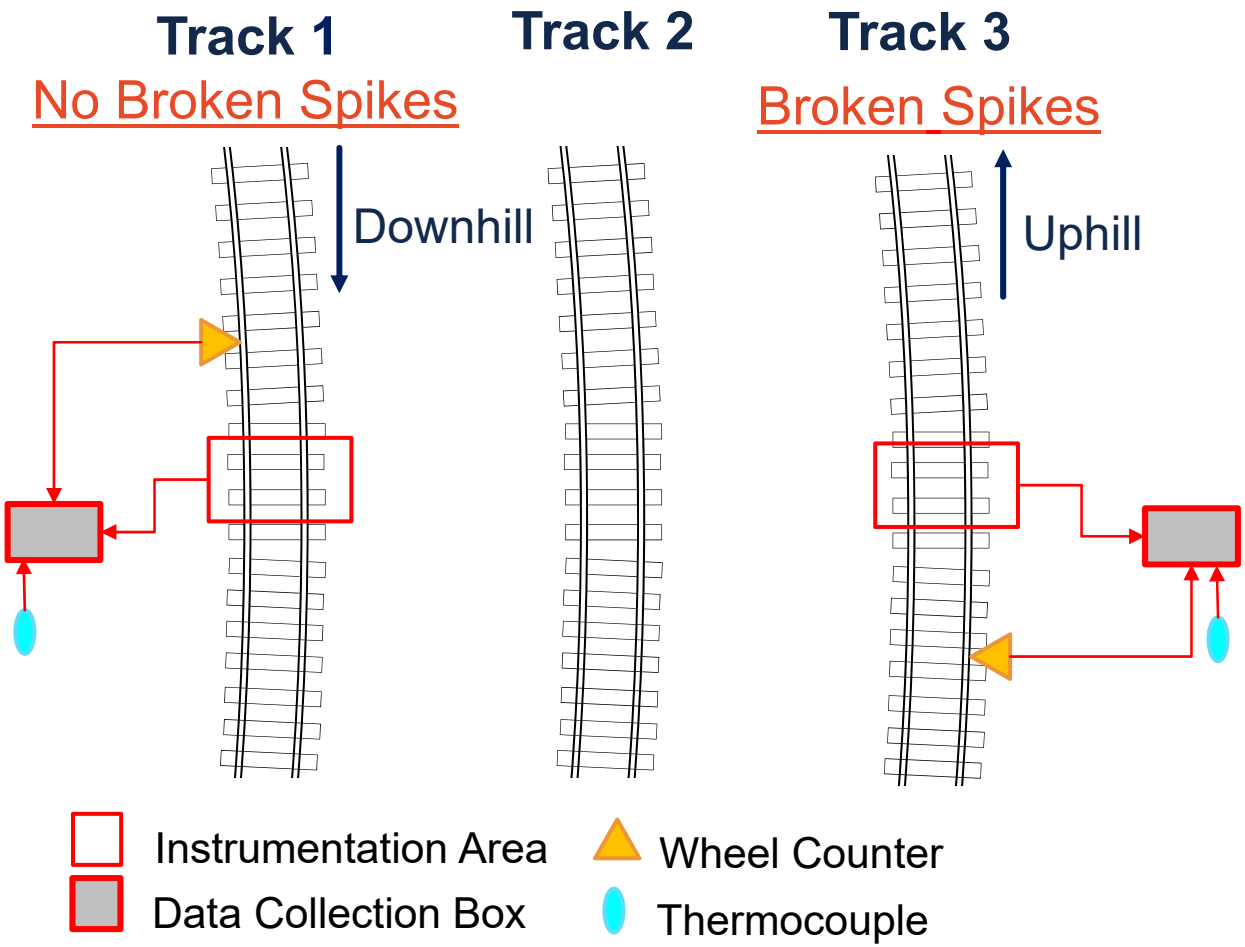
Phase II Laboratory Investigation

Understanding Fastener Mechanics

- Single spike testing
- Single system longitudinal load test
- Full-scale track tests



Phase II Field Instrumentation Plan



- **Data to be collected**
  - Loading environment (Vertical, Lateral, Longitudinal)
  - Rail and fastener displacements

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NURail Center

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