

# Use of Laser Triangulation and Deep Neural Networks (DNNs) for Railway Track Safety Inspections

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## Project Introduction and Update

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Industry Partners Meeting

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Tucson, AZ



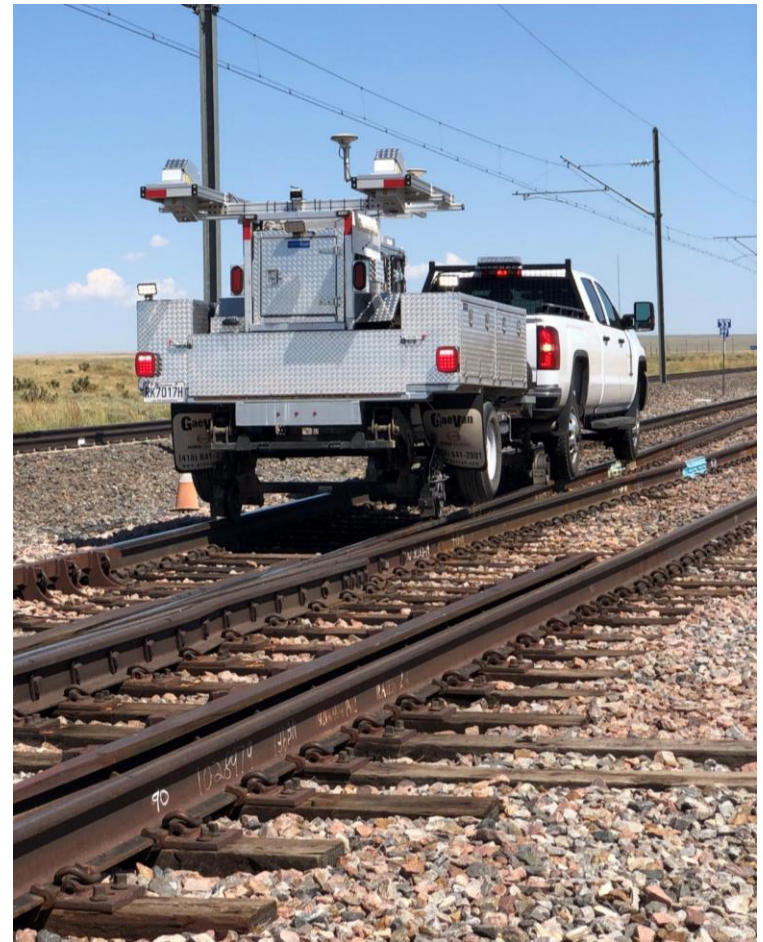
U.S. Department of Transportation  
**Federal Railroad Administration**



# Outline



- ▶ Background and approach
  - Project overview
  - Current inspection characteristics
  - Potential inspection improvements
- ▶ Technology and methodology
  - Railmetrics prior experience
  - Deep neural networks
  - Data collection methods
- ▶ Progress to date
  - Features of interest
  - Areas inspected
  - Current results
  - Challenges
- ▶ Path forward



# Project Overview



- ▶ **Mission** – Evaluate the potential for use of Laser Triangulation and Deep Neural Network (DNN) technologies to provide value-added inspection data to existing geometry car inspection systems
- ▶ **Objectives:**
  - Improve railway network safety through improved reliability and robustness of track inspections
  - Provide value-added inspection data to existing geometry car inspection systems in operating conditions that include both:
    - Locations without a priori knowledge (e.g., the first inspection of a given route)
    - A posteriori scenarios (e.g., a repeat inspection of a route)
- ▶ **Timeline:** May 2019 → August 2020

## Project Partners:



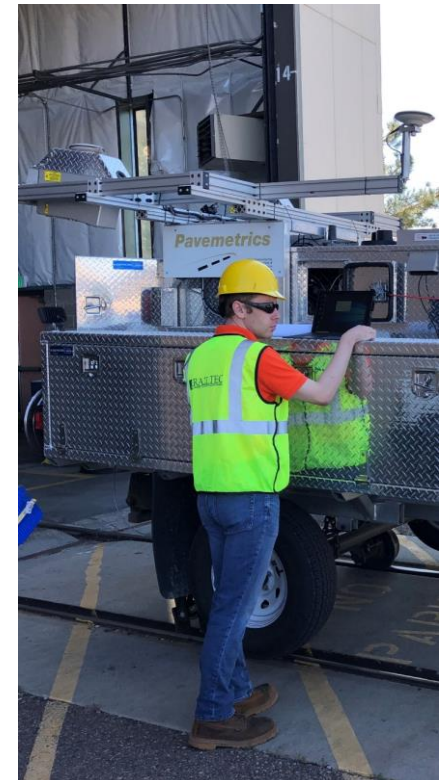
## Industry Partners:



# Project Approach



- ▶ Use Railmetrics sensors to **collect data on the High Tonnage Loop (HTL)** at the Transportation Technology Center (TTC).
  - Tonnage accumulated by Facility for Accelerated Service Testing (FAST) train operations.
- ▶ Scans will be analyzed by RailTEC @ Illinois researchers in order to identify locations with defects and/or degradation in order to **build a condition database**.
- ▶ This database will be used by Railmetrics to subsequently **train a DeepCNet-based neural network** in the automated identification of features of interest.
- ▶ **Evaluate performance of the DNN** through the analysis of a separate set of test data and comparison of the DNN's outputs to experts.
  - Goal of at least 75% agreement between the DNN and expert raters



# Current Methods and Proposed Technology



## ▶ Current visual inspections (FRA Class 6+)

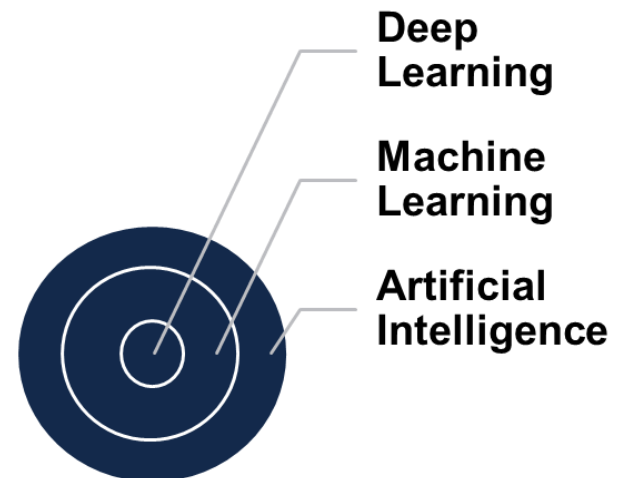
- Costly
- Time consuming
- Risk associated with personnel on track
- Impact track capacity



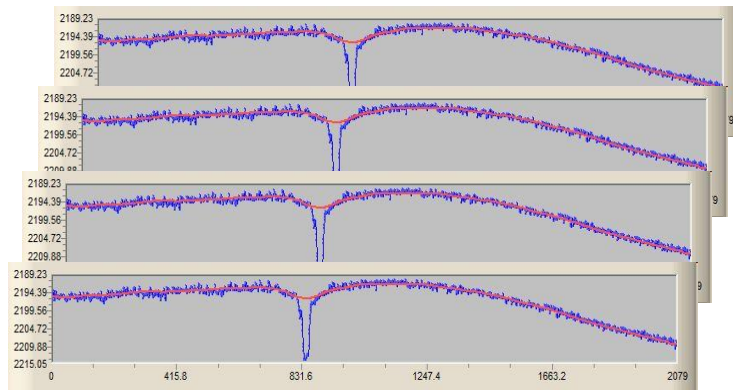
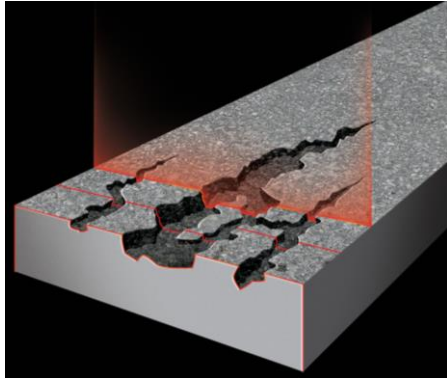
## ▶ Alternative technologies

- Machine learning (in use in industry)
  - Process large amounts of data
  - Reliant on human recommendations
  - Limited to problems designer can solve

- Deep Neural Network (DNN)
  - Subset of machine learning
  - Develop own analysis method
  - No retraining

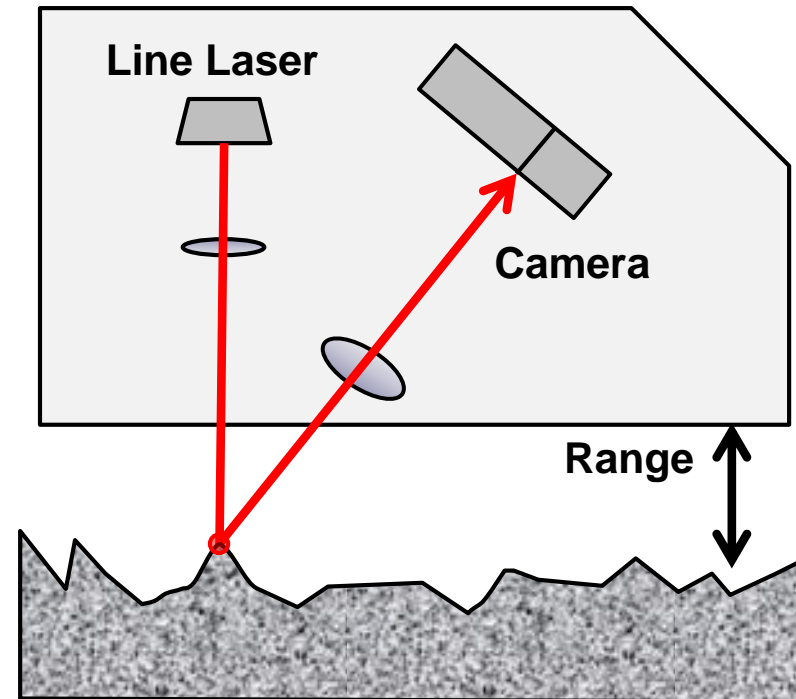


# Railmetrics Data Collection



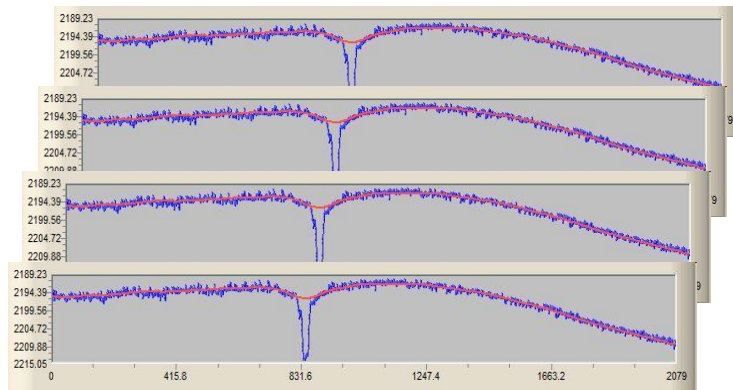
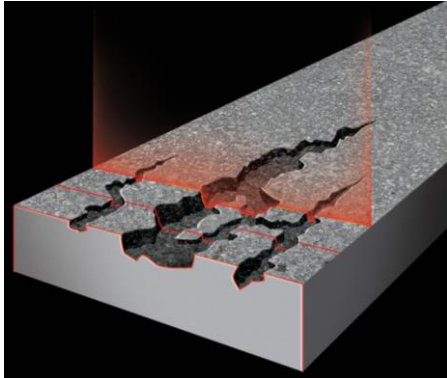
**Successive Scans are Compiled to Form a Continuous Image**

## LRA/L Sensor



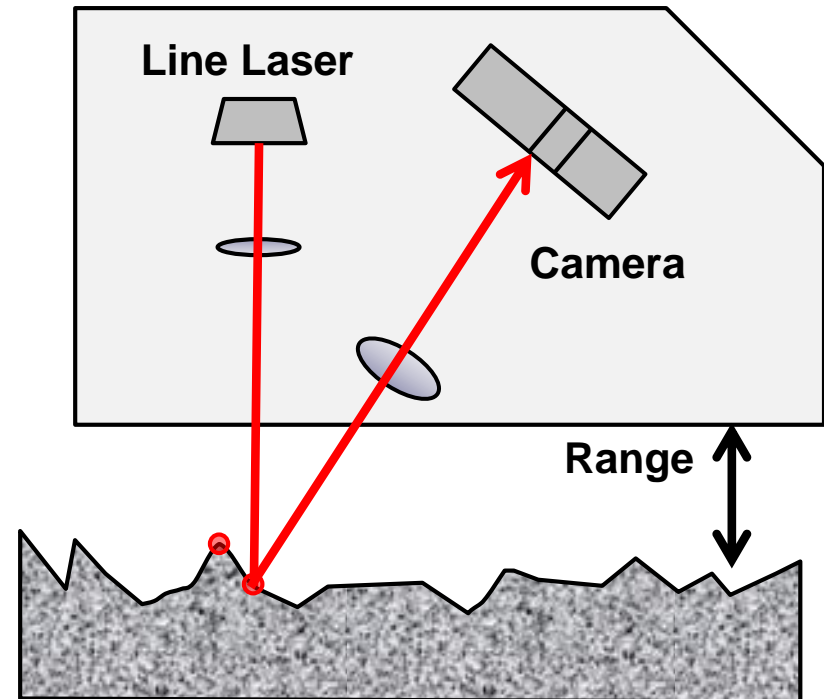
**Road/Runway/Tunnel/Rail Surface**

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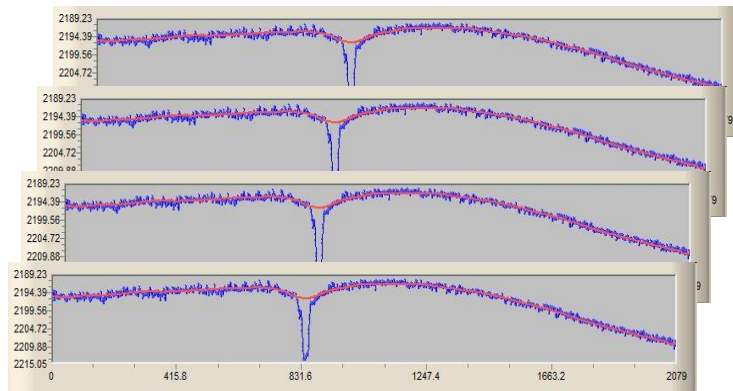
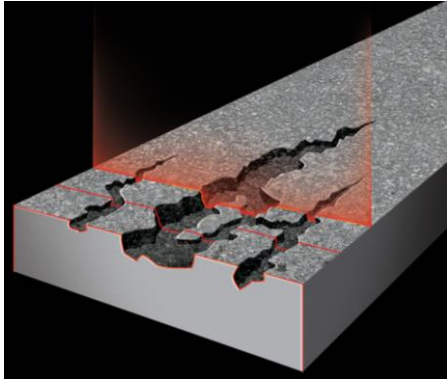
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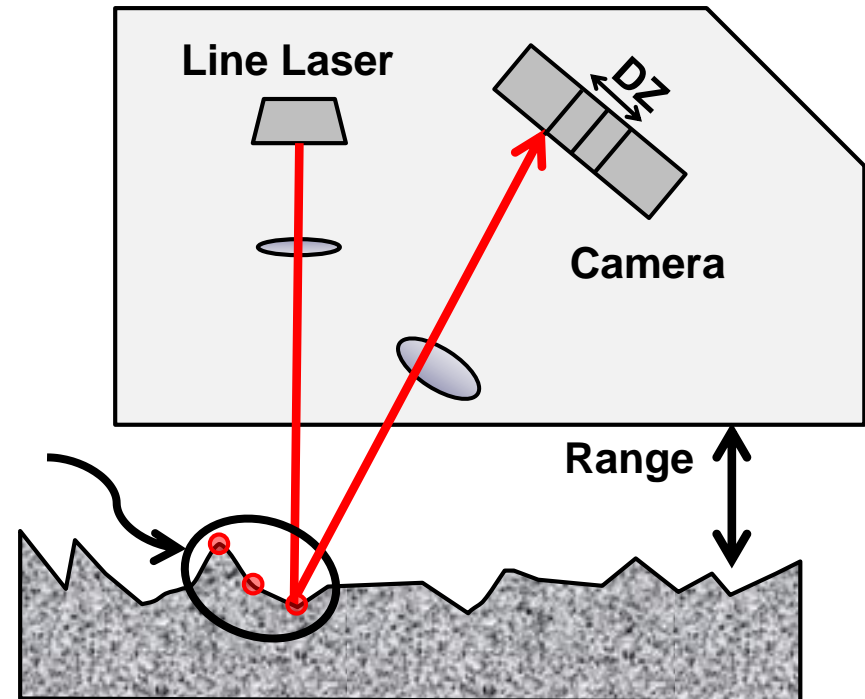
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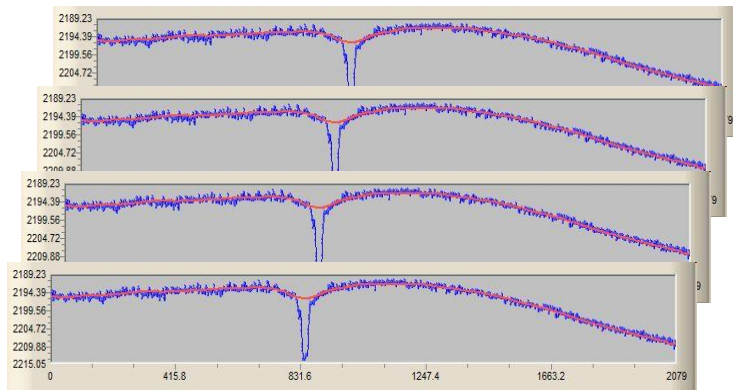
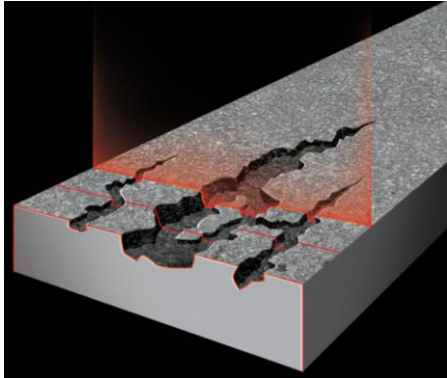
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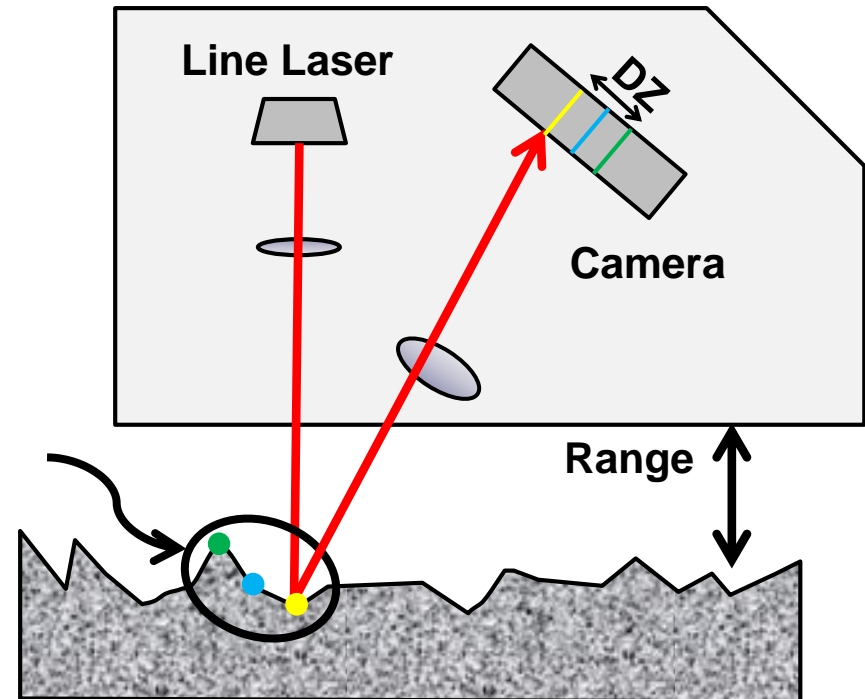
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# Railmetrics Data Collection



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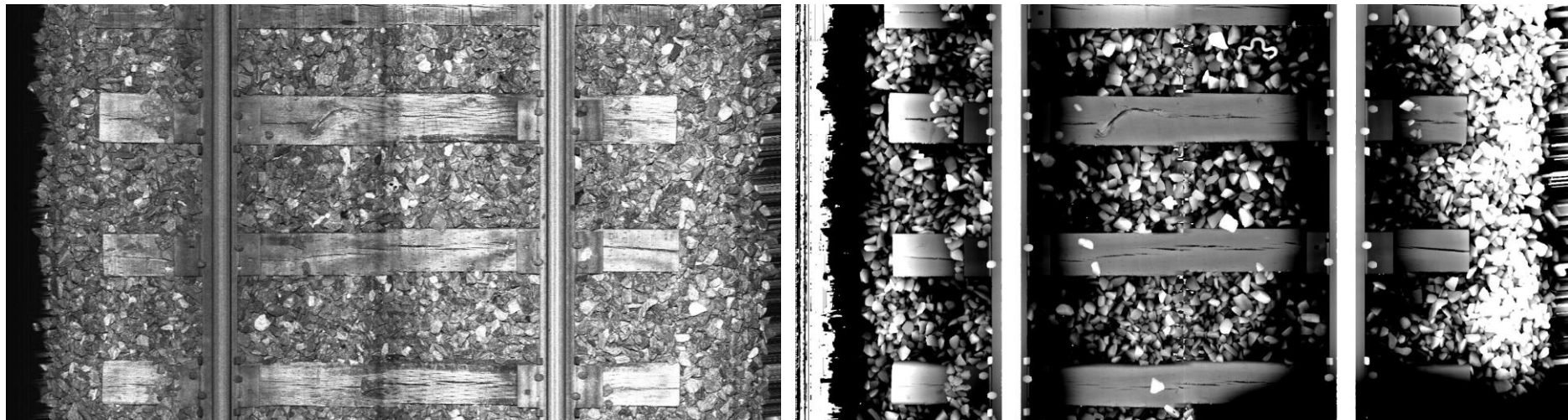


**Road/Runway/Tunnel/Rail Surface**

# Scanning Technology



- ▶ Two types of scans combined for analysis
  - Unique to Railmetrics
  
- ▶ Intensity Scan
  - Measure intensity of laser light reflected off surface
  - Produce black and white image
  
- ▶ 3D Scan (“Range”)
  - Measure elevation
  - Produce 3D profile



# Intensity Scan

A 3D intensity scan of a mechanical part, likely a gear or a similar component, rendered in grayscale. The scan shows the surface texture and geometry of the part, with a prominent circular feature in the center. The background is a dark, textured surface.

Content Developed in Part by Railmetrics

# 3D Scan (“Range”)

A 3D point cloud scan of a textured surface, possibly a book cover. The scan is rendered in grayscale, showing a dense grid of points and lines that form the shape of the object. The surface has a rough, fibrous texture. The scan is viewed from an isometric perspective, showing the top and side surfaces.

Content Developed in Part by Railmetrics

# Combined Result



Content Developed in Part by Railmetrics

# Benefits of Two Scans



**This is an “Intensity Image” Can you tell which ties/sleepers are bad just by looking at them?**

# Benefits of Two Scans



This is a “Range Image”; we can now detect a bad tie that appeared to be OK based on the Intensity Image alone

# High-Rail and Trailer



- ▶ Optical wheel encoder
  - Back of trailer
  - Rolls on wheel
  - Trigger image capture
- ▶ Data capture
  - RailTEC and/or Railmetrics personnel on site at TTC
  - Images relayed from trailer to computer in high-rail vehicle
  - Uploaded to Railmetrics database for further processing and transfer to RailTEC



# Project Breakdown Overview



## ▶ Phase 1:

- Task 1 – Project initiation
- Task 2 – Definition of safety parameters for analysis
- Task 3 – Sensor installation and field data collection
  - Ground truth inspection
  - High rail inspection



## ▶ Phase 2:

- Task 4 –Development of features-of-interest database
- Task 5 – DNN training

## ▶ Phase 3:

- Task 6 – DNN testing and evaluation
- Task 7 – Final reporting and results dissemination

# Ground Truth Walking Inspections



- ▶ Record of features of interest
  - Spreadsheet list of features prepared prior to arrival
  - Use tablet to categorize ties by type, section and number
    - Concrete, timber, composite, etc.
  - Subcategories for features
    - Missing spike, center crack, broken clip, etc.

	CONCRETE						
Tie #s	Cent. Crack	Long. Crack	RSD	Broken Shoulder	Insulator Defect	Missing Dowel	Broken Dowel
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							



# Summary of Progress to Date



## ▶ Ground Truth Inspections

- Documented fifteen different features of interest
  - Multiple of same defect documented once per tie
- Approximately 7,500 ties inspected

## ▶ Data Collection via High-Rail

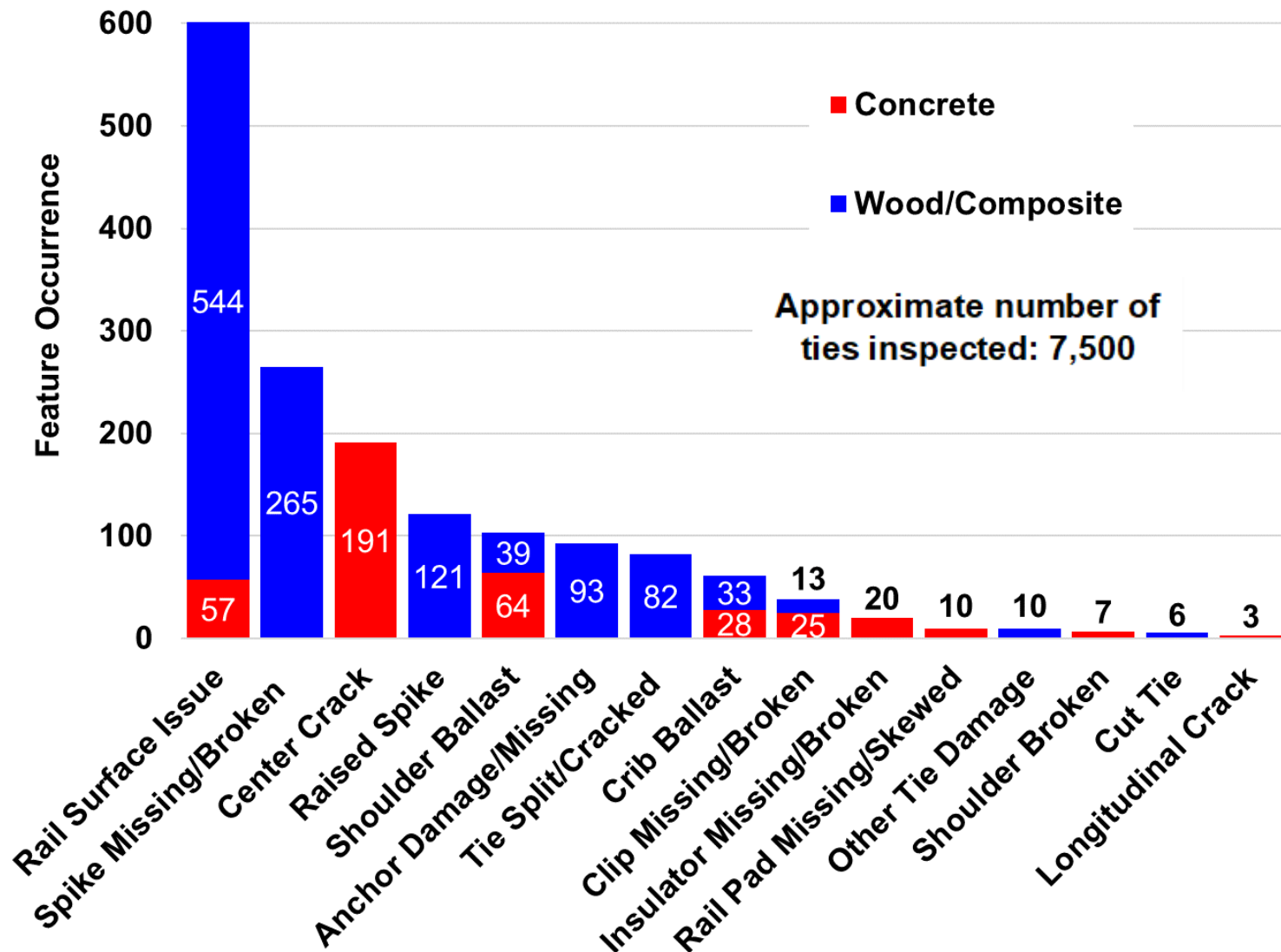
- 5 weeks of data collection
- Average 3 runs per week

## ▶ Challenges

- Inconsistent judgement
  - Raised spike
- Major issues repaired before detection
  - Broken tie plates
  - Clusters
- Intentional variance interferes
  - Different manufacturers for similar tie plates



# Ground Truth Summary



# Path Forward



- ▶ Weekly data capture on HTL
  - During Fall 2019 FAST operations
  - Walking inspections as needed
  
- ▶ Initial processing of data for automatic identification of features (Railmetrics)
  
- ▶ Tag new “features of interest” (RailTEC)
  
- ▶ Train DNN (Railmetrics)
  
- ▶ Evaluate DNN performance (Railmetrics)



# Acknowledgements



- ▶ Research Sponsor:



- ▶ Subcontractor:



- ▶ Industry Partners:



- ▶ Field Testing Support:



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# Thank you for your attention!

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**Railmetrics**



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