GREX®

Real Rail Solutions

Tie Life Condition Assessment and Tracking: More Information = Better Management

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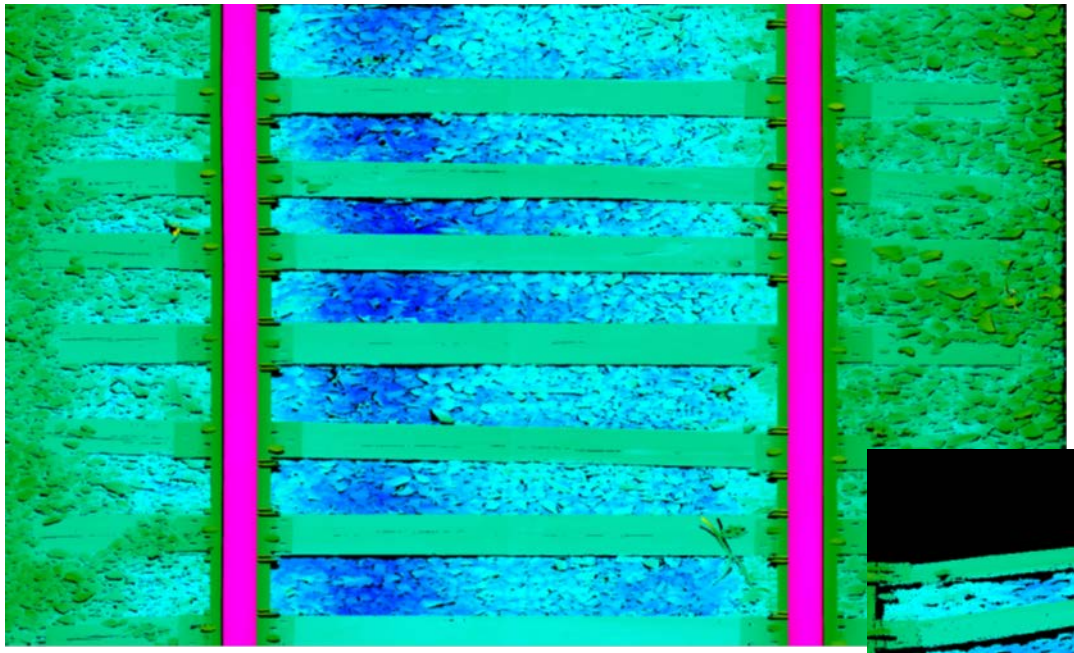
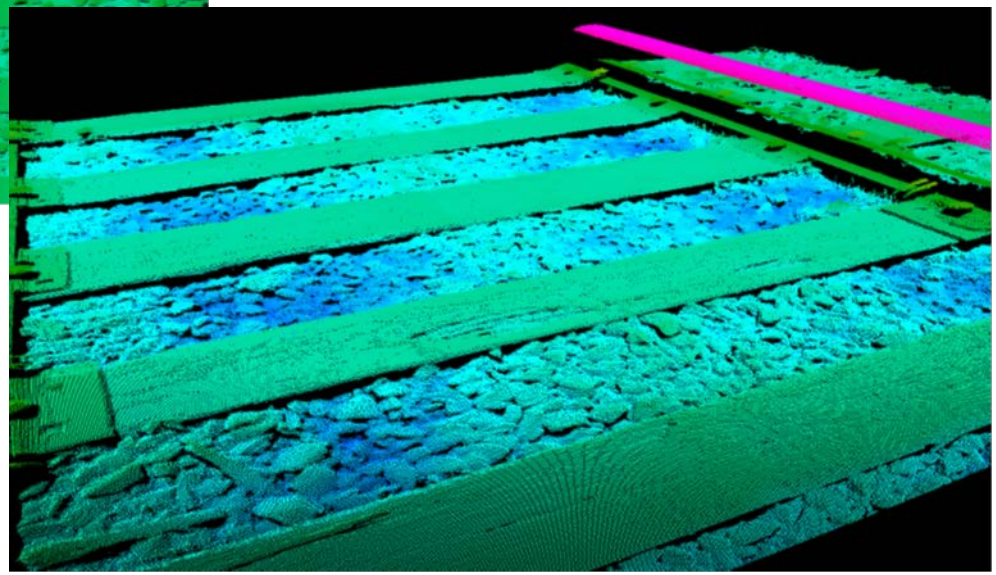
PART 1: FIELD INSPECTION & EXPERIENCE

Aurora® 3D Tie Inspection

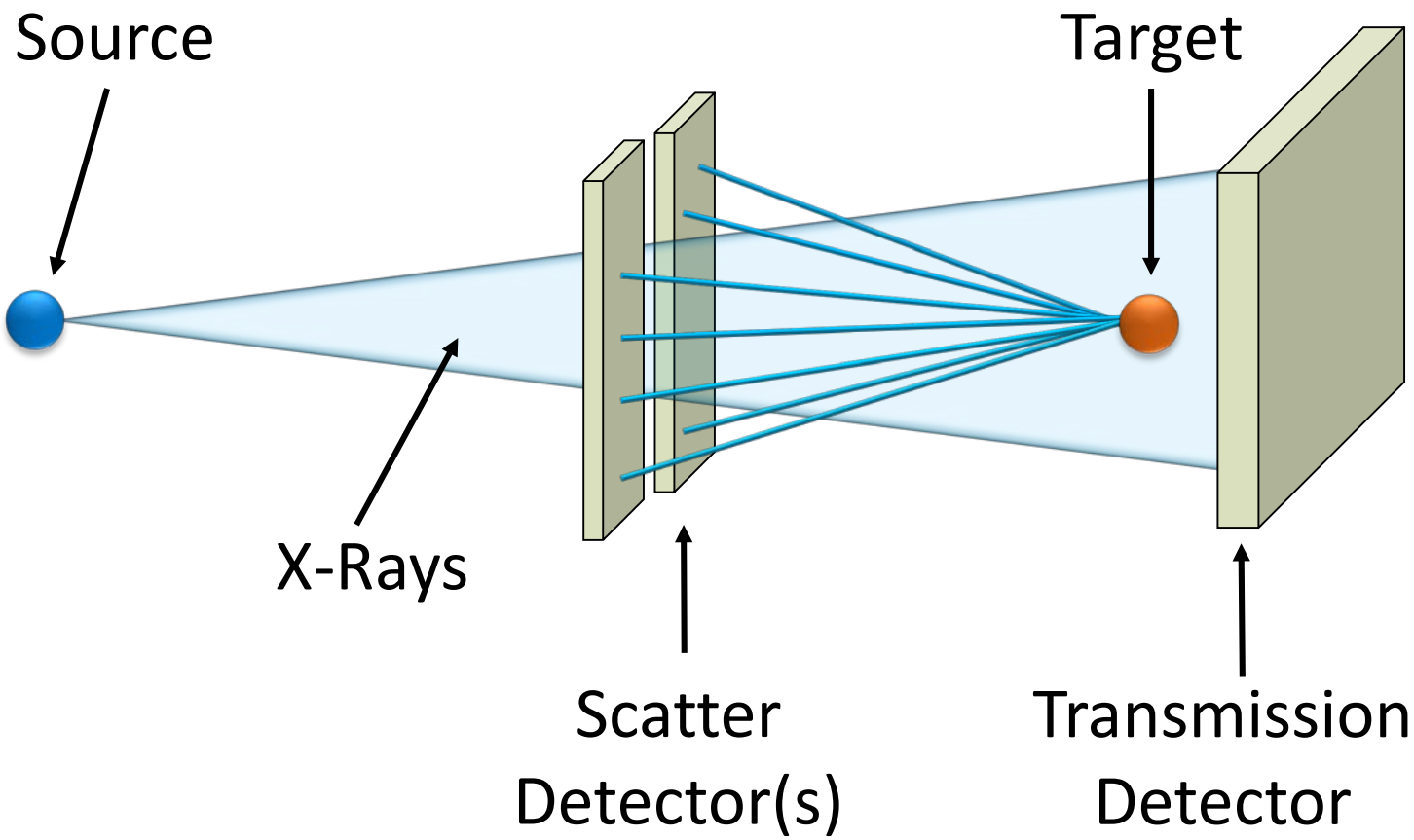


- Surface Condition
- Split
- Plate Cut
- Warped
- Broken



"This is great, but what about hollow ties?"

X-Ray Transmission vs Backscatter

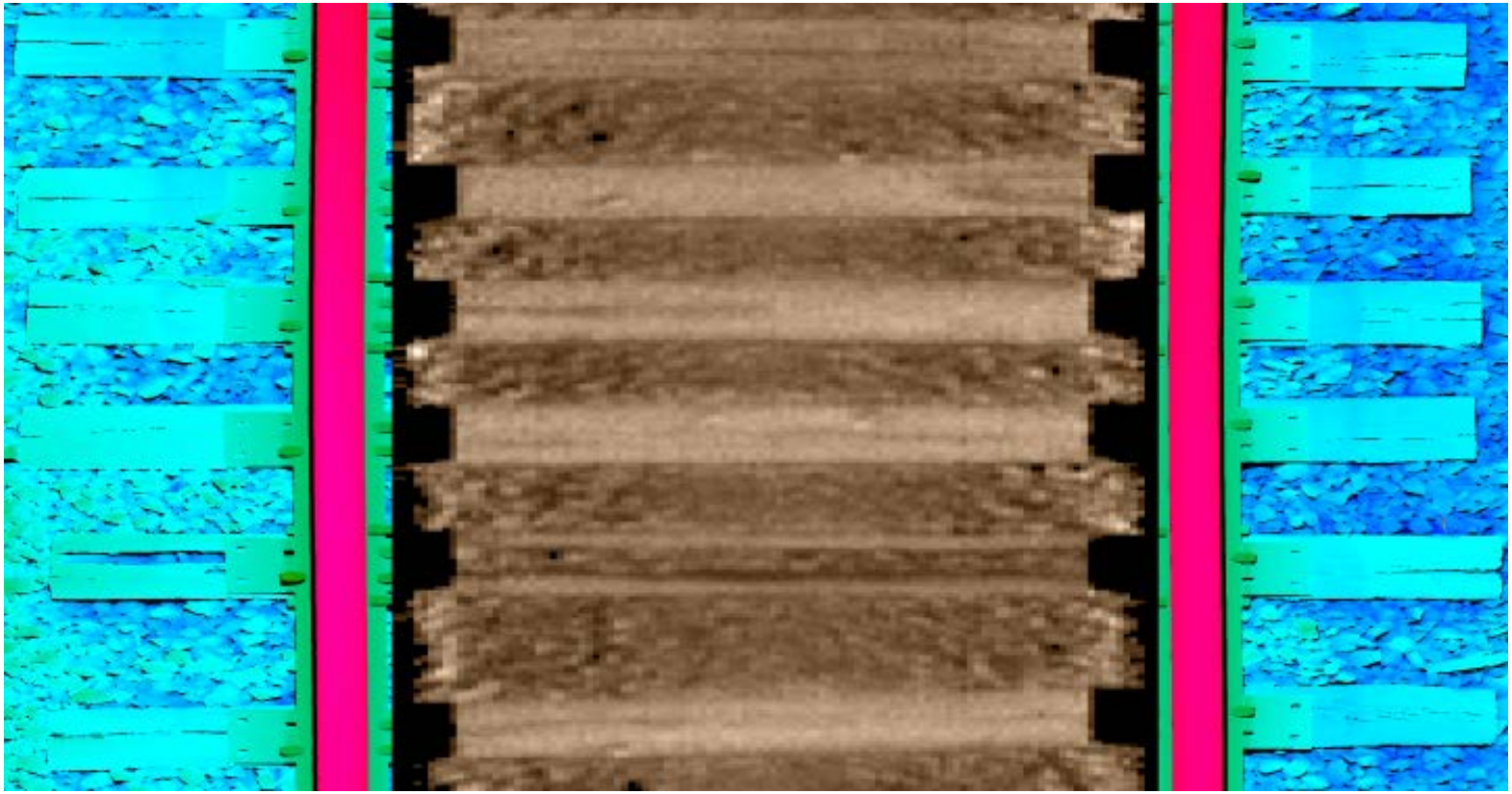


Aurora Xi® Inspection Platform

Combines 3D surface scan with X-Ray backscatter internal imaging

25 MPH continuous scanning

Aurora Xi® – Internal Defective Tie Cluster



Defective Tie Cluster – Field Inspection

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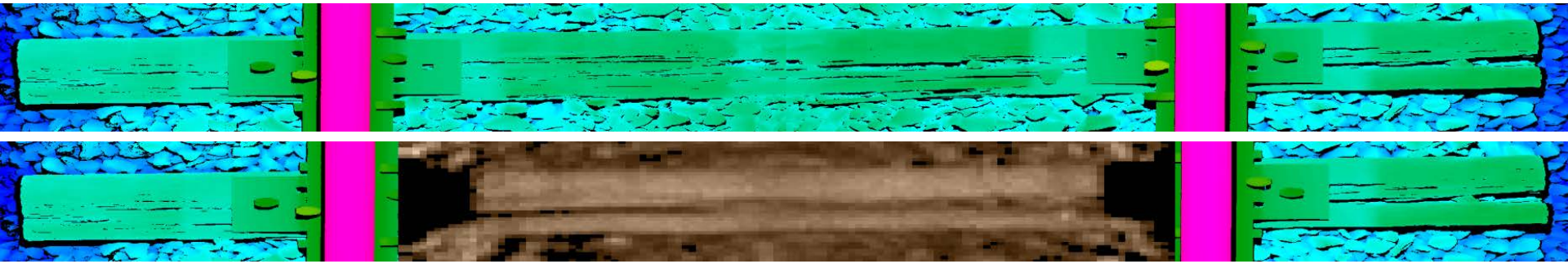
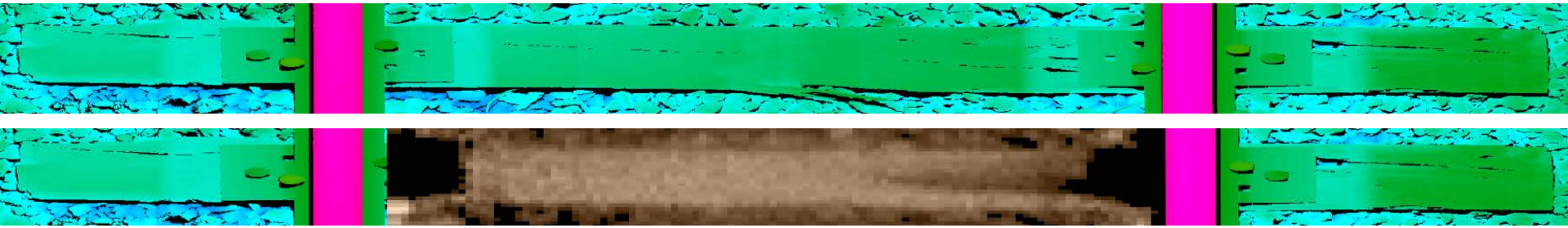
Predominant Internal Failure Modes

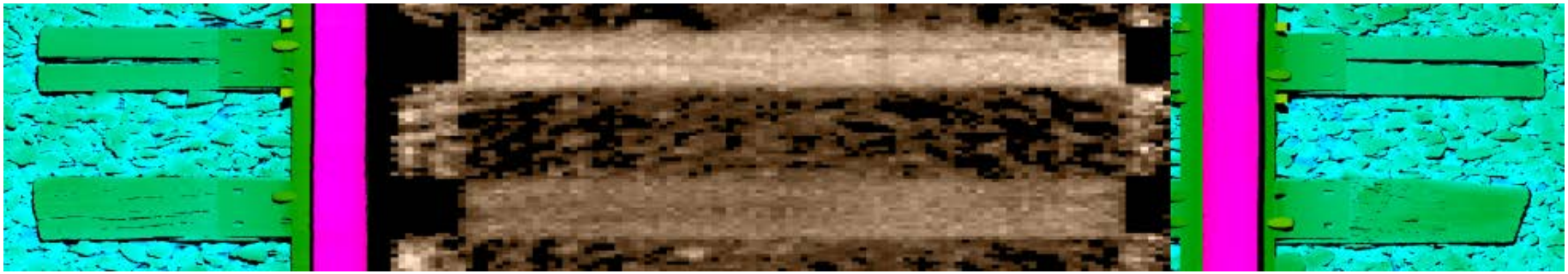
Deep Splitting



Localized Hollowness



Uniform Density Loss



X-Ray Grading Scale

Good

Marginal

Bad

Failed

Texas Chainsaw Massacre/Experiment

More Destructive Testing (Failed Tie)

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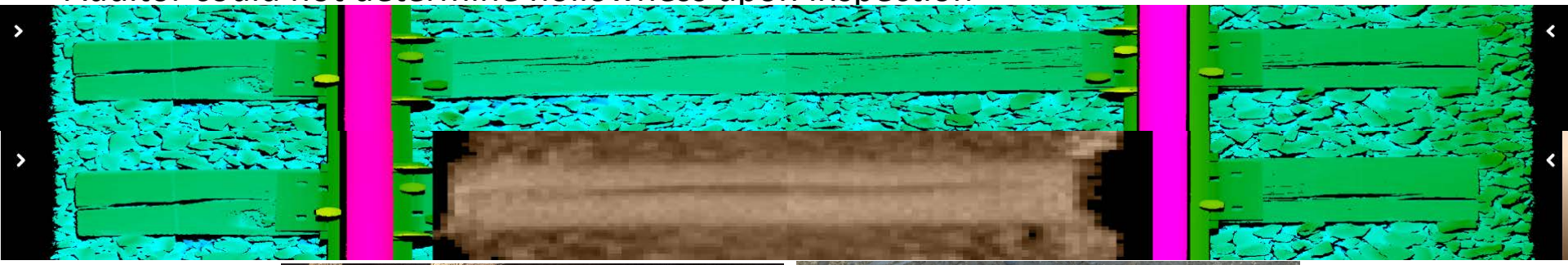
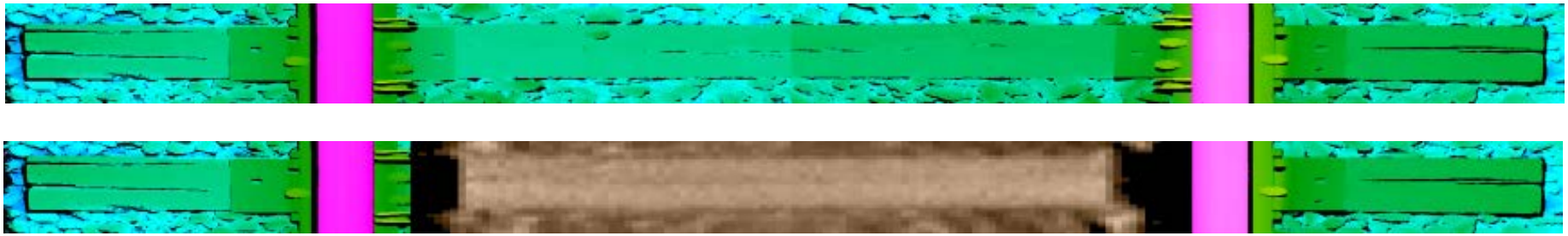
- Tie # 5570: Surface Score = 2.0, Internal Score = 4.0, Xi Score = 4.0
- Auditor could not determine hollowness upon inspection



- Image above left: Tie with white paint line to indicate where to cut
- Image above right: Cross section demonstrating sizable void in center of tie, top surface fell apart during cut

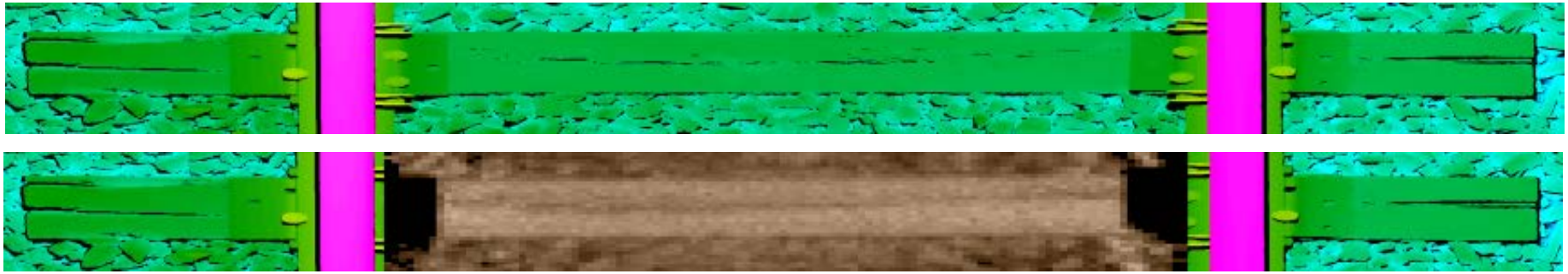
Observed High Degradation Rate

01/15/2016 – Surface Score 1.6, Internal Score 1.7 = **Marginal Tie**



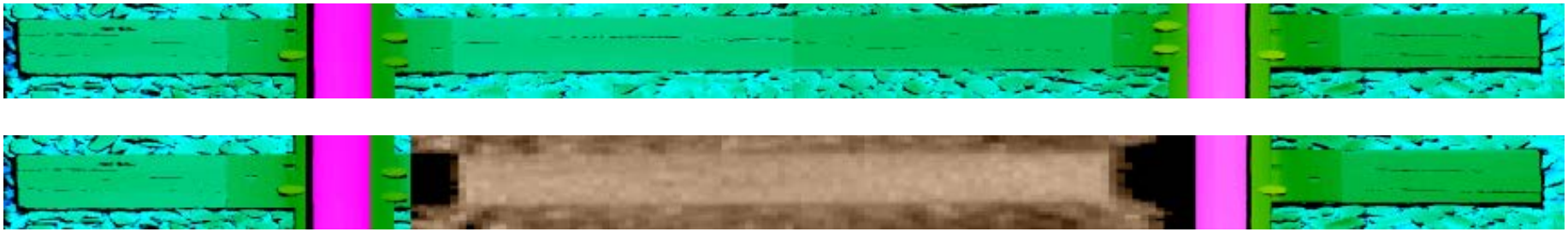
22 Months Elapsed…Some Tie Replacement Occurred

11/10/2017 – Surface Score 1.8, Internal Score 3.7 = **Failed Tie**



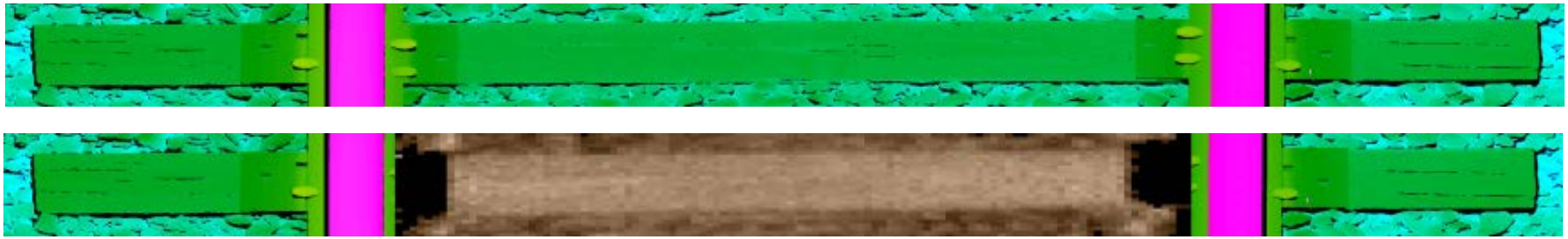
Observed Low Degradation Rate

01/15/2016 – Surface Score 1.0, Internal Score 1.1 = **Good Tie**



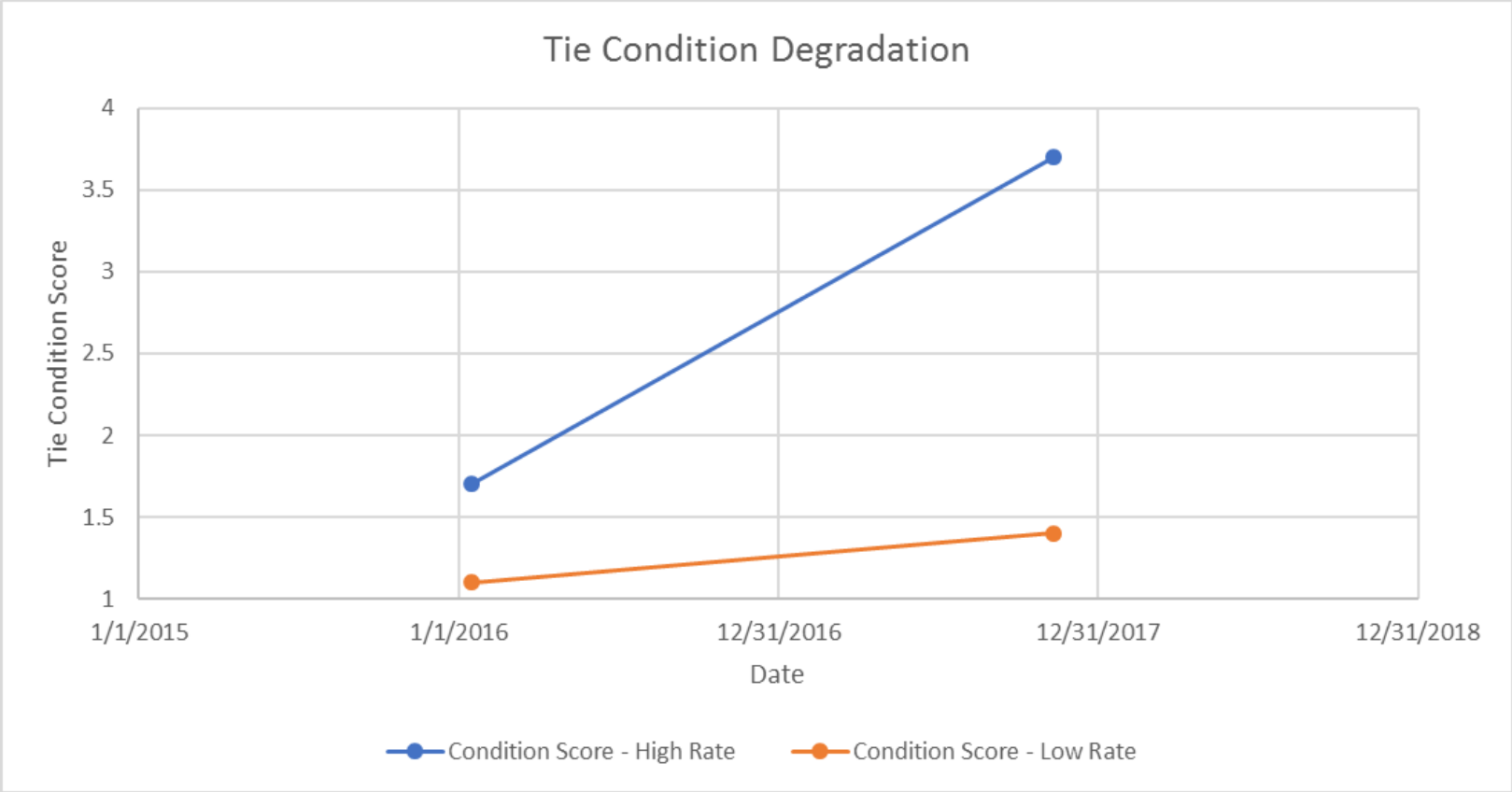
Same 22 Months Elapsed…

11/10/2017 – Surface Score 1.1, Internal Score 1.4 = **Good Tie**



* 5 ties away from previous tie

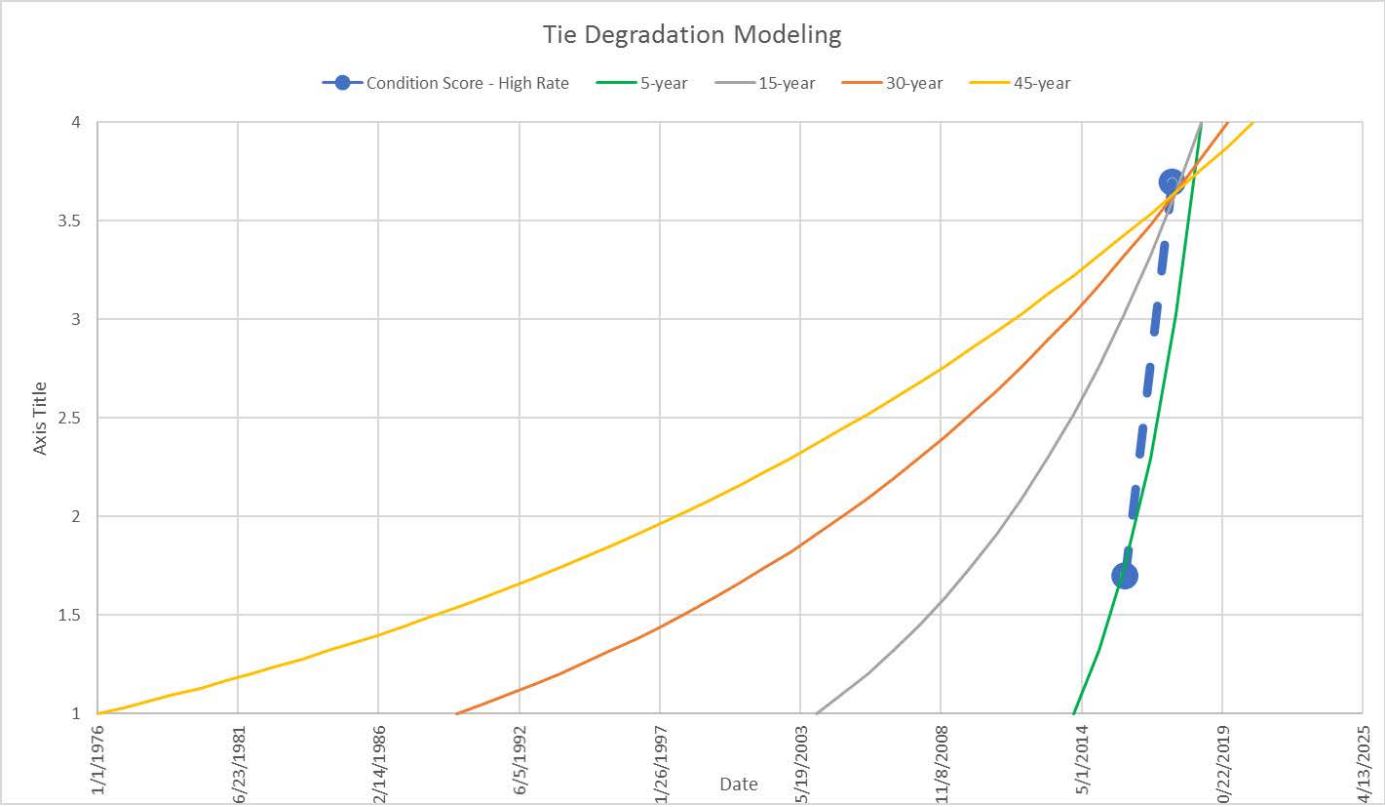
Short Term Tie Condition Trending



- No context of service environment
- No history

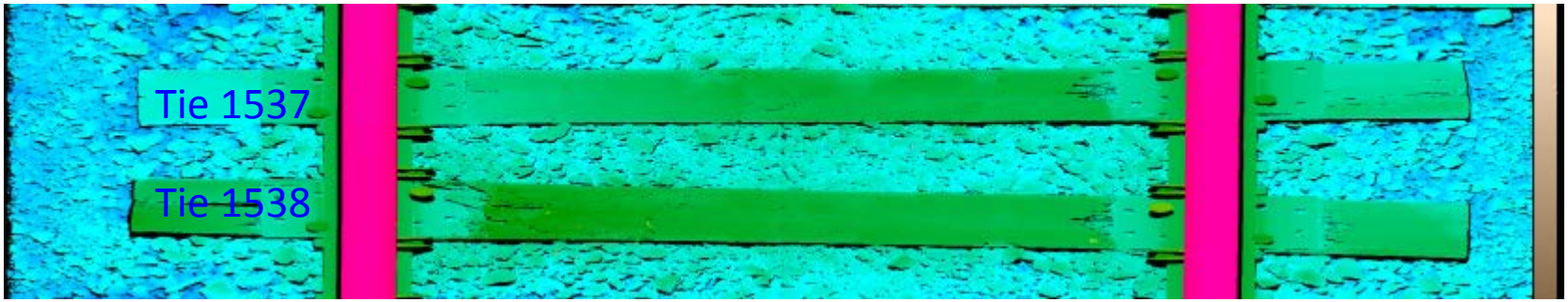
Characterizing Full Tie Life History

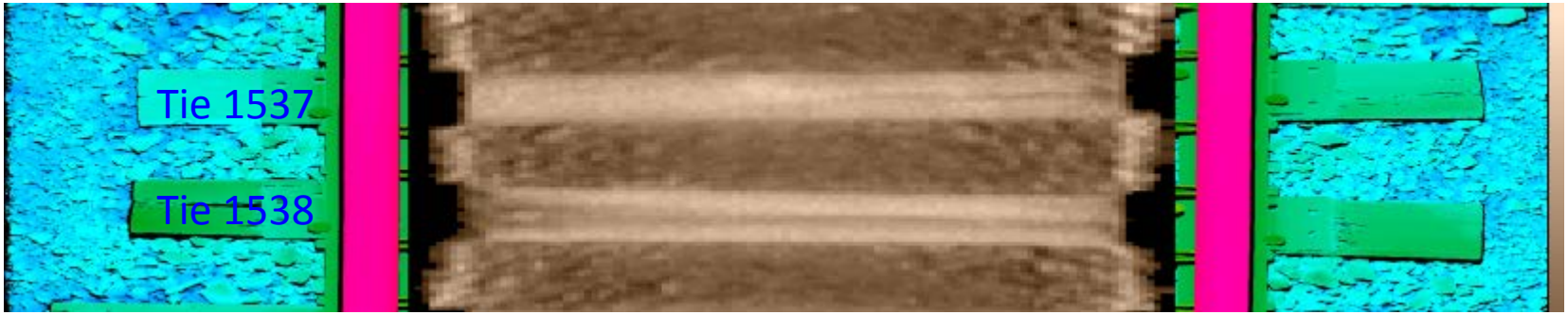
- Initial condition
- Inspected condition over time
- Predicted end of service life



Rapid Tie Disintegration

Aurora Surface & X-Ray Scans 01/14/2016





Rapid Tie Disintegration

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Picture taken 01/18/2017

Building Tie History Database

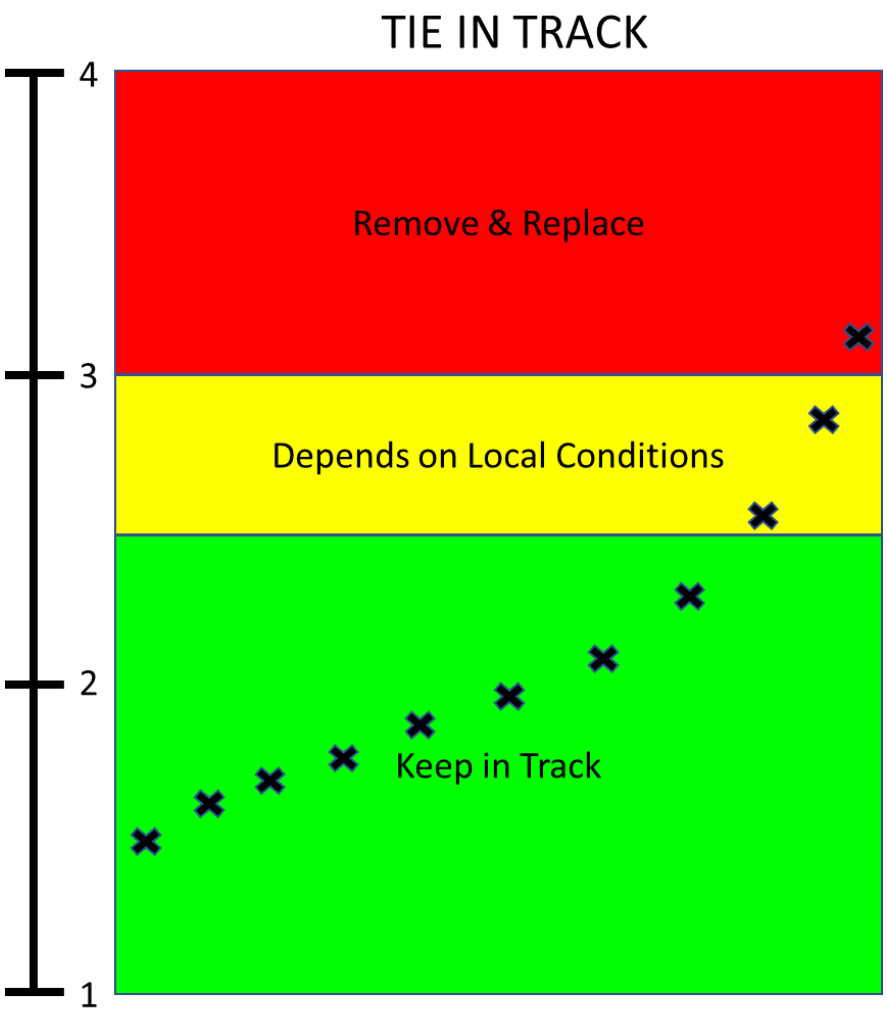
Aurora Xi

- Tie Surface Condition
- Tie Internal Condition
- Plate & Fastener
- Track Curvature
- GPS Coordinates
  - Decay Zone
- Line & Milepost
- Proximity to:
  - Rail Joints
  - Switch, Crossing, Bridge

RR Added Information

- Tonnage
- Traffic Characteristics
- Gradient
- Track Geometry Condition
- Ballast Condition
- Last T&S Cycle
- Other Maintenance Activity

Tracking Tie Condition Over Life, Part 1



PART 2: ECONOMIC INCENTIVES

Railroad Tie Capital Budgets

- Crossties Magazine, October 2017:

New Crosstie Purchase Forecast, in Millions, 2018			
Type	Track	Switch	Bridge
Class I	15.85	0.51	0.15
Short Line*	5.26	0.74	0.44
Total	21.11	1.25	0.59
* extrapolated			22.95

- 2017 RTA conference purchasing forum
  - Class I RRs continue to demand wood ties
  - One of highest capital spend categories is wood ties

- Recent issues with tie quality

Optimizing Tie Life Cycle – Replace Too Soon

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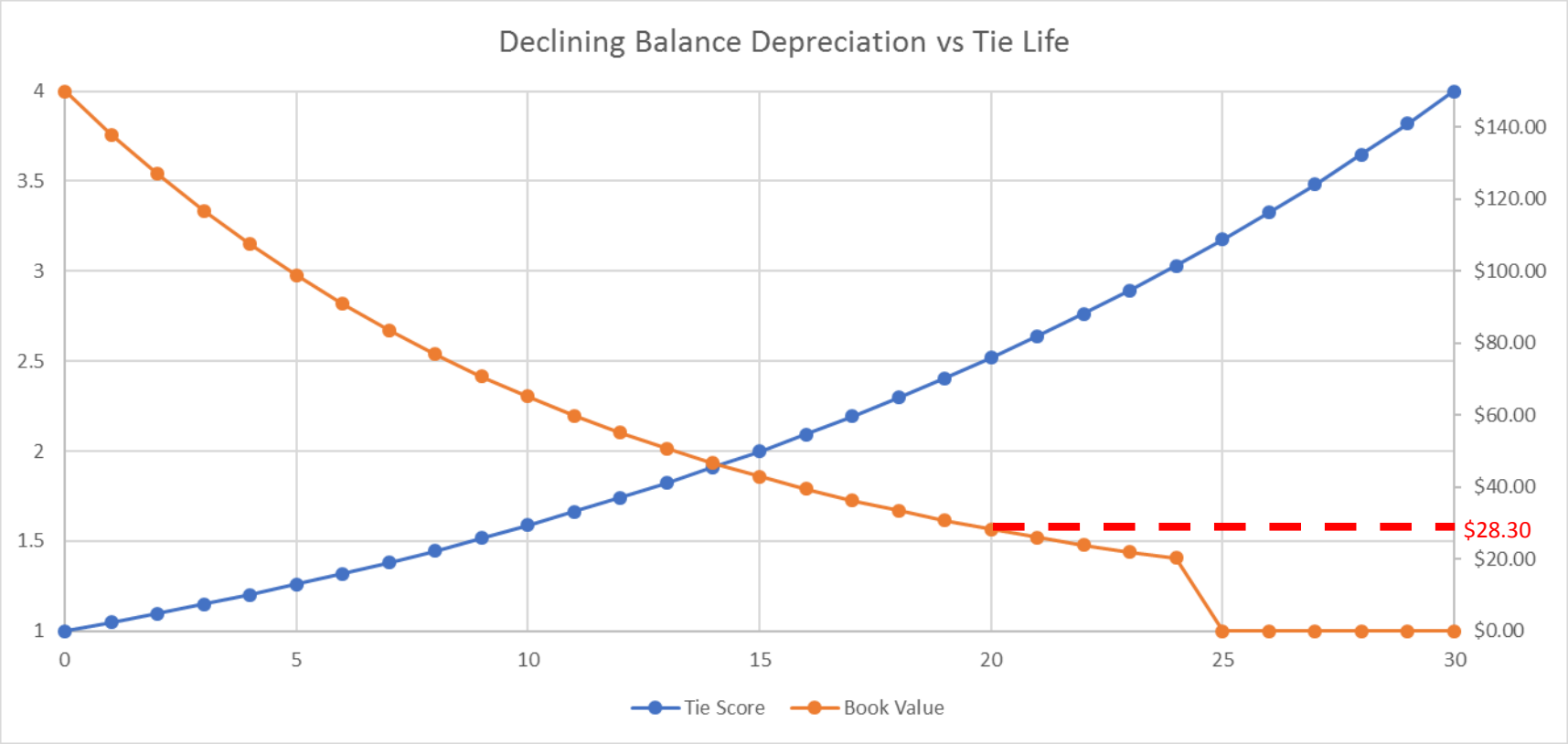
- Exponential degradation over 30 years
- $150 initial value, $0 salvage value after 25 years



- Replacement at 20 years is loss of $28.30 in remaining value.
- For 2.5M tie program with 2% early replacement this is $1.42M

Optimizing Tie Life Cycle – Replace Too Late Neighbor Effects

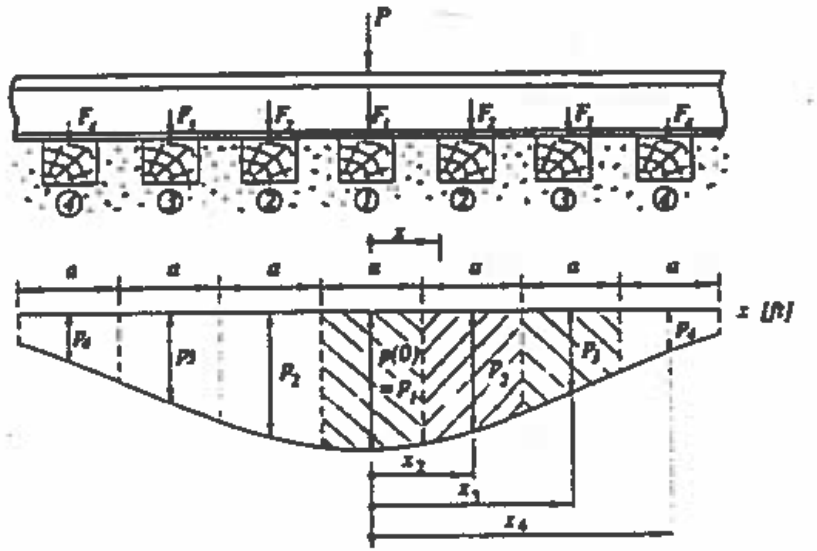


Fig. IV.9. Determination of rail-seat forces from the *p(x)*-curve

Rail Seat Force	F1	F2	F3	F4	F5
Fn	6928	5865	3588	1863	759
% of Load	23.1	19.6	12	6.2	2.5
132RE rail					
k = 3000 lb/in^2					

If Tie #1 not supporting rail:

- Increased rail deflection
- Increased rail bending stress
- Increased rail seat forces on neighbor ties
- **Increased neighbor tie degradation rate**
- Increased bearing pressure on ballast

Kerr, Arnold D. "Fundamentals of Railway Track Engineering" 2003.

PART 3: INITIAL CONDITIONS

Plant Tie Scanner Motivation

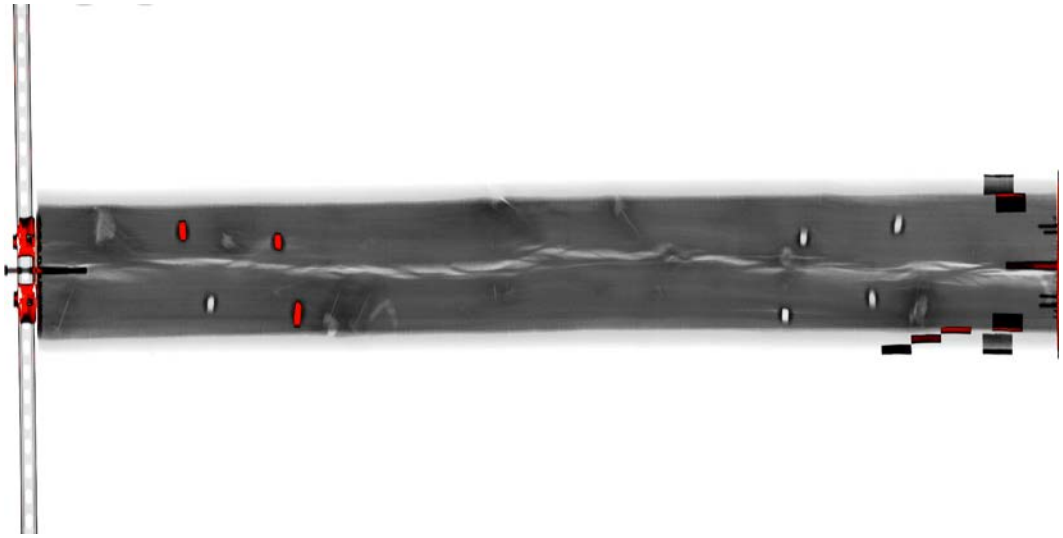
- Railroads spend about $2.4B/yr on ~23M crossties
- Human inspectors guess at the internal density and quality
- Transmission and/or scatter x-ray radiography can directly measure internal density and quality

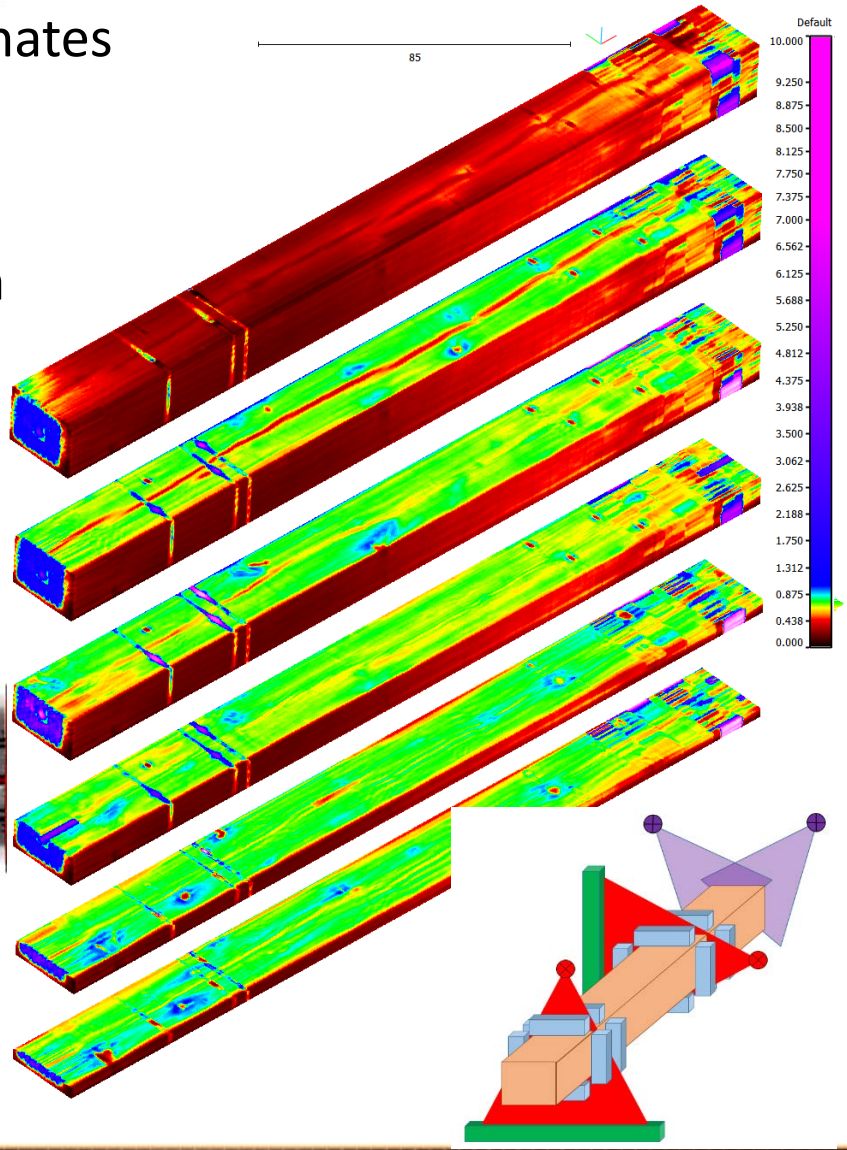
New Tie Inspection System Proof-of-concept

- An untreated crosstie was mounted on a rotating pivot.
  (It's easier to rotate the tie than rotating the heavy shielded X-ray tube.)
- The crosstie was rolled through the fan beam to make transmission images.

Plant Tie Scanner – 2D and 3D

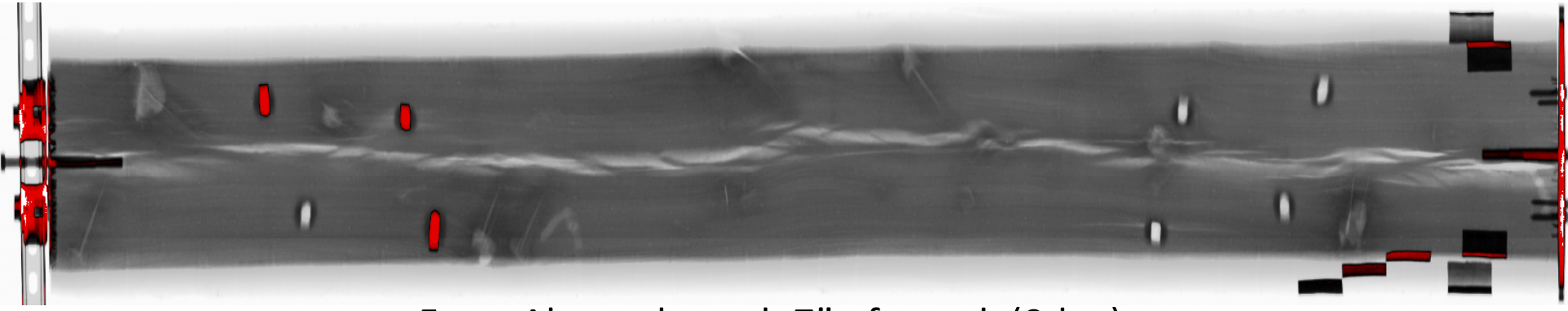
- One or more fan beams of x-rays illuminates the crosstie
- The surface is scanned and imaged
- 2D and 3D (CT) images are formed from transmitted and/or scattered x-rays



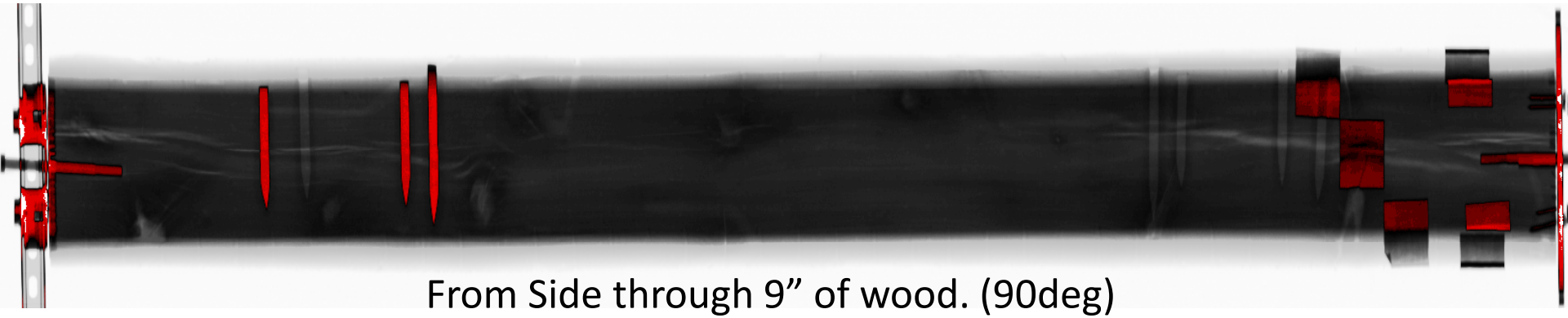


Perpendicular X-ray Perspectives

- Wood Density
- Splits
- Rot
- Other imperfections & variances



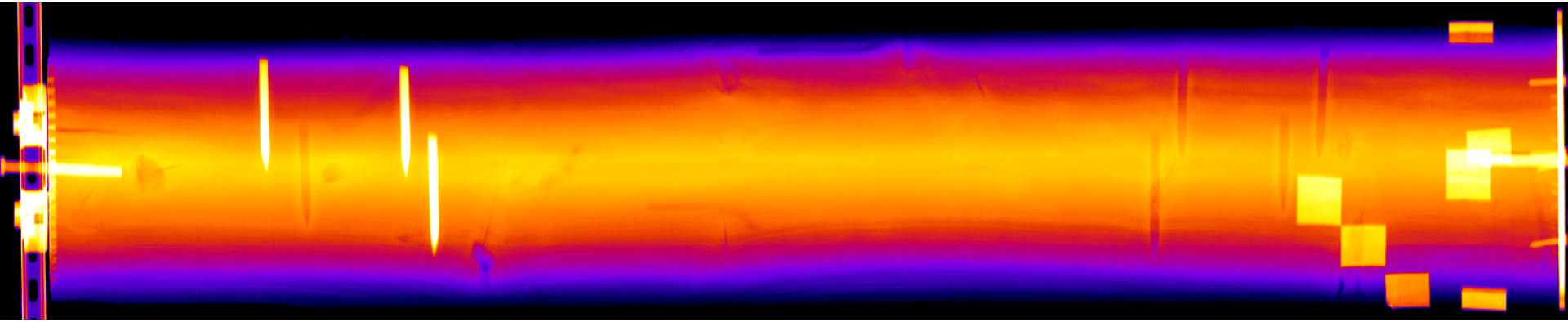
From Above through 7” of wood. (0deg)



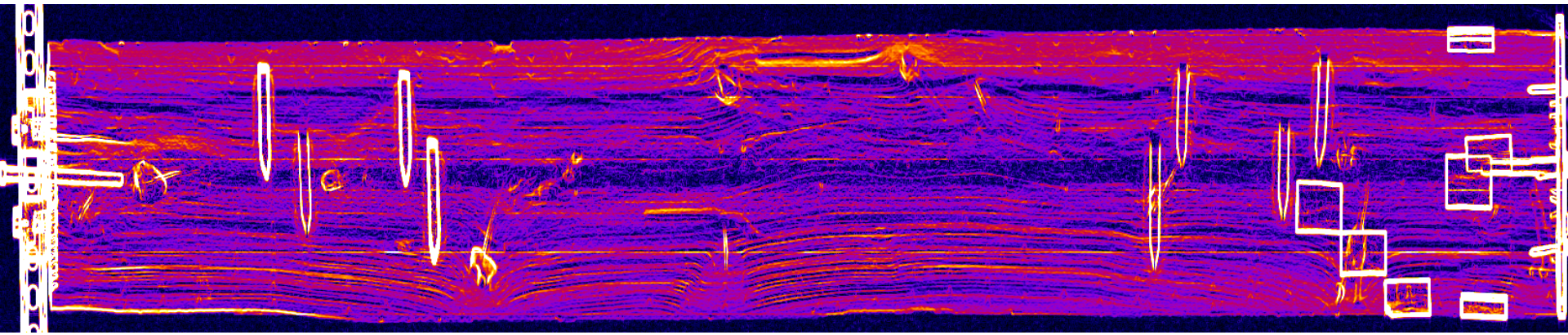
From Side through 9” of wood. (90deg)

Image Enhancement

- Wood Density + Surface Characteristics → Species ID
- Treatment Penetration



Any color scale of raw/processed data is possible.

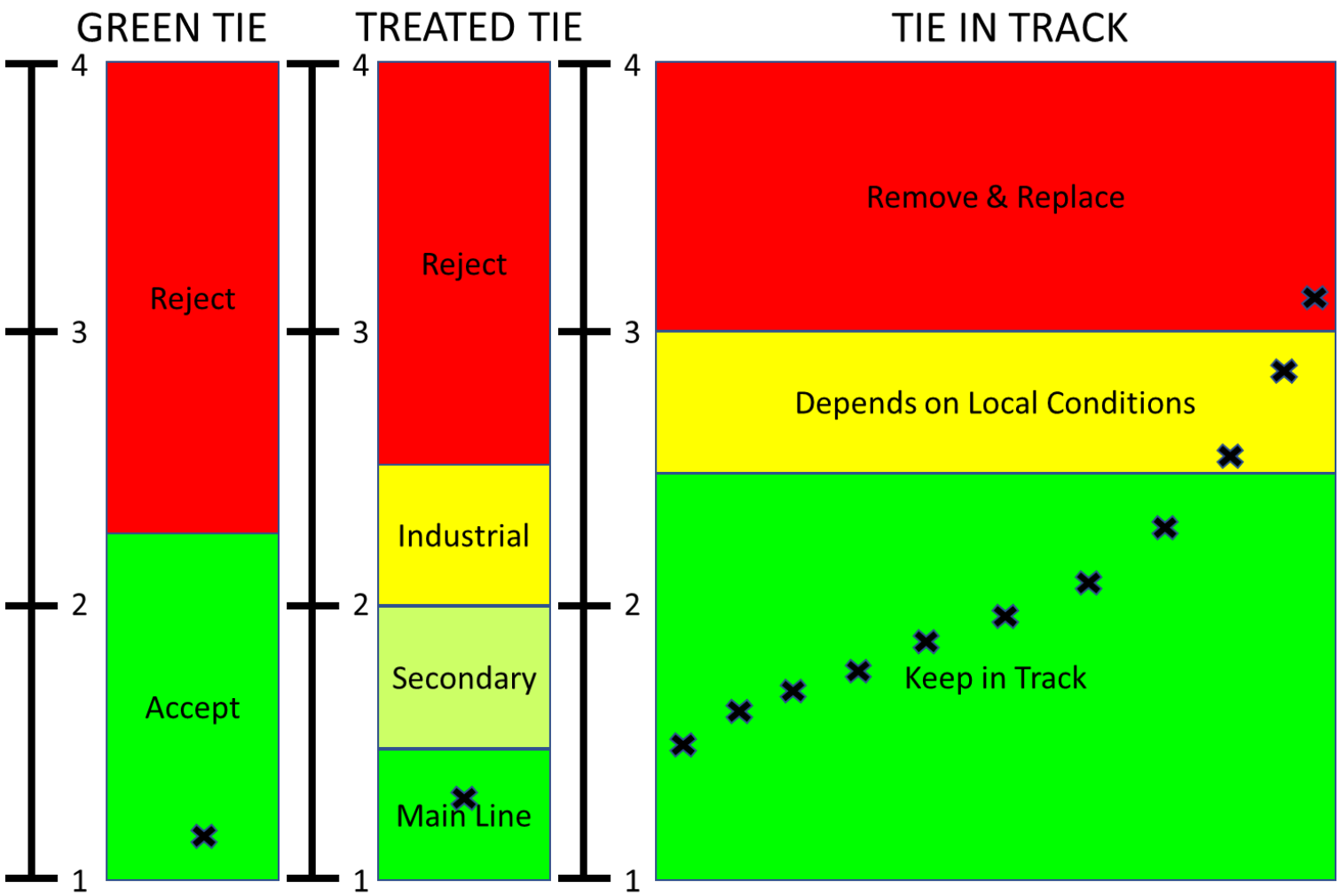


Gradient views and edge detection is also possible.

Tie Inspection at Production Plant

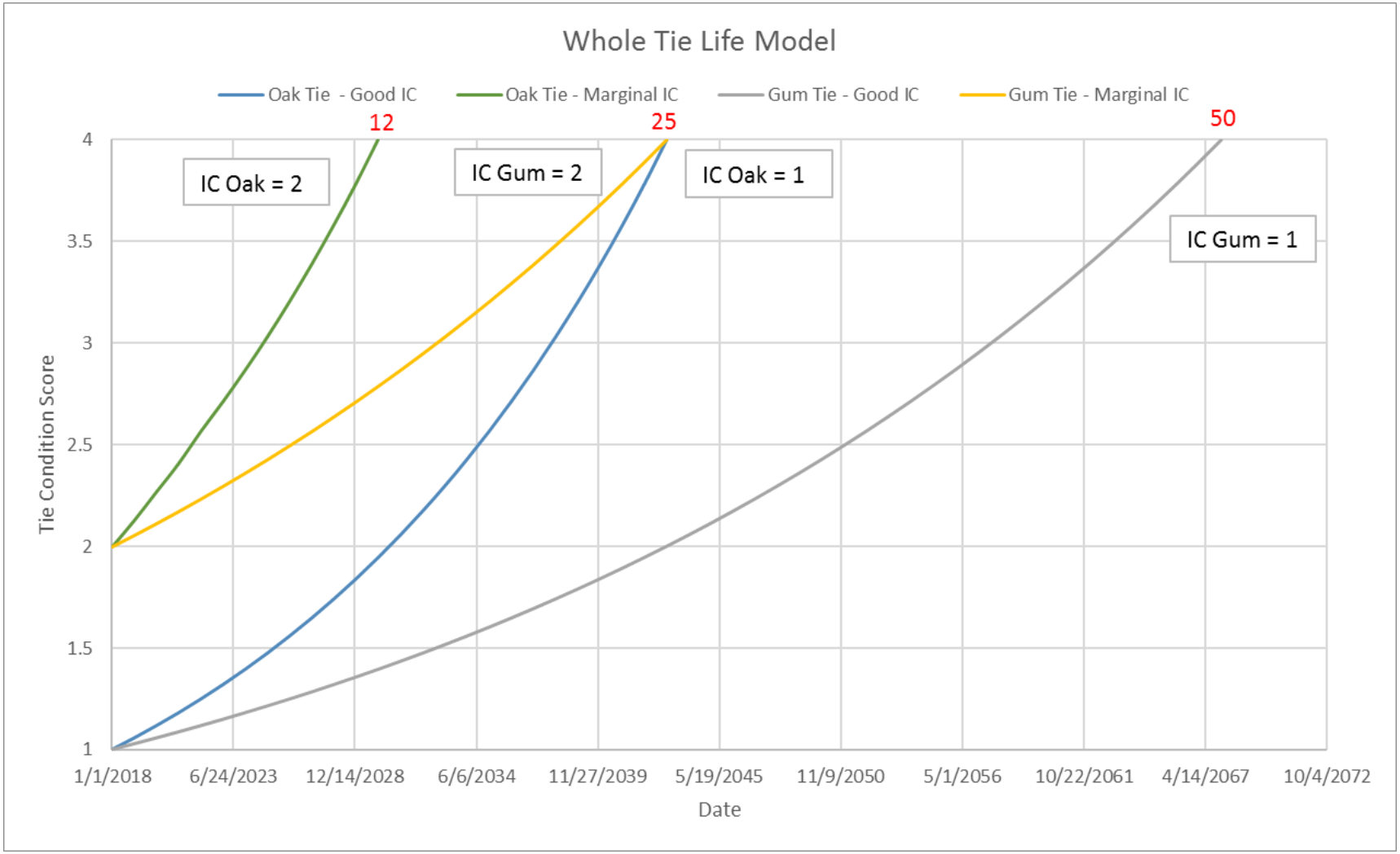
- Scan Green Wood
  - Surface Metrics
    - Species ID
    - Dimensions
    - Splits, bark seams, shake, etc.
  - Internal Metrics
    - Density variations
    - Rot, voids
    - Potentially a ‘moisture’ image
- Scan Treated Wood
  - Surface Metrics
  - Internal Metrics
    - New density
    - Treatment saturation
    - Treatment penetration depth
- **Attach all information to individual tie**
  - ID Tag

Tracking Tie Condition Over Life, Part 2



PART 3: END GOALS

Predicting End of Tie Life



Executing Surgical Tie Replacement

- Tie Replacement Logic needed
- Tie Allotment/Budget constraints

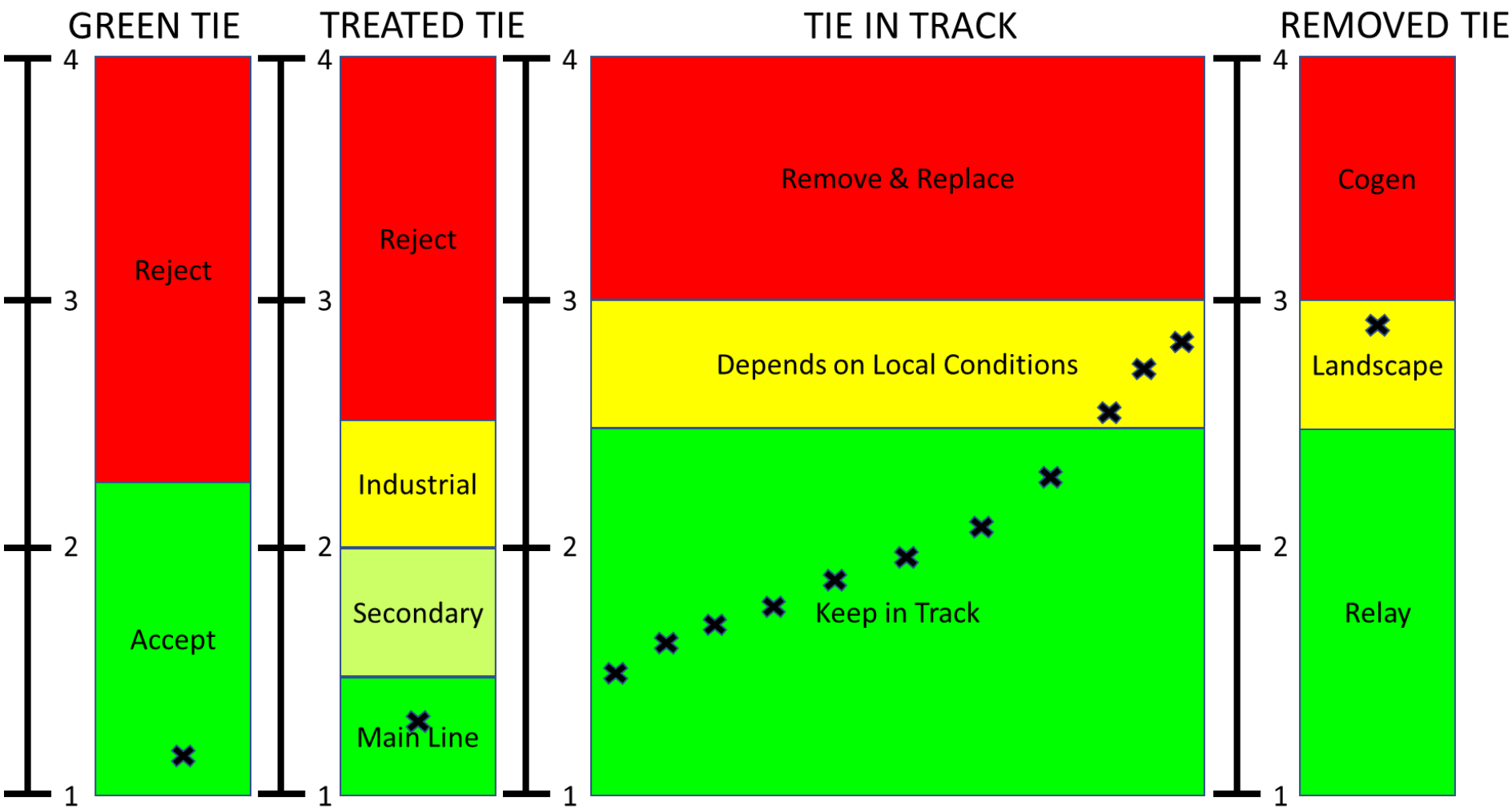
Grade Threshold = 1105/mile

Replacement Logic = 1183/mile

Budget Constraint = 950/mile

- Automated Tie Marking System →

Tracking Tie Condition Over Life, Part 3



Building a Tie Life Cycle Model

- Inputs for track characteristics
- Determine attributes
  - Species
  - Size
- Determine initial condition
  - Density
  - Defects
- Measure condition in service over time
- Predict failure life/replacement threshold
- Replace the correct ties

Big Data - Aurora Program History

- Large scale historical data for several North American railroads
  - Aurora – Laser Surface Scanning
    - 12 years of experience
    - 210,000 miles
    - 664 M ties scanned overall
  - Aurora Xi – Backscatter X-ray Inspection
    - 4 years of experience
    - 54,000 miles
    - 170 M ties scanned by X-ray
  - 550 TB raw data
- Repeated scanning
  - Locations scanned annually since 2012
  - Locations scanned 6+ times since 2014

Challenges

- ID Tag on new tie
  - Transfer tag to in-track service
- Tracking tie in service
  - Positive ID of same tie
  - Optimal evaluation conditions
    - Ballast, mud, etc.
- Logging accurate track properties
  - Tonnage
  - Environmental factors
  - Maintenance activity
- Dealing with Incomplete Data
- System for tracking asset over life of 20-50 years
- Volume of assets → **BIG DATA**
  - 1000 track miles is > 3M assets
- Data storage/retrieval

End Goals - The Future

- Complete first-of-a-kind bridge tie x-ray scanner.
- Combine data streams.
- Leverage true neural-net AI on combined data.
- Improve predictive capabilities and accuracy.
- Accomplish every task faster and more efficiently.
- Invent entirely new sensors for new measurements.