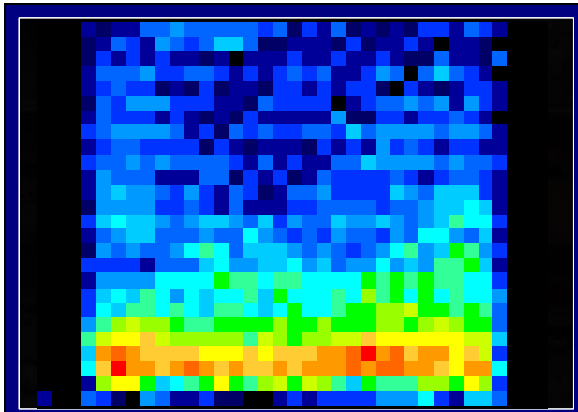
Effect of Lateral Load on Rail Seat Pressure Distributions



Joint Rail Conference

Colorado Springs, CO

3 April 2014

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U.S. Department of Transportation
Federal Railroad Administration

RAILTEC
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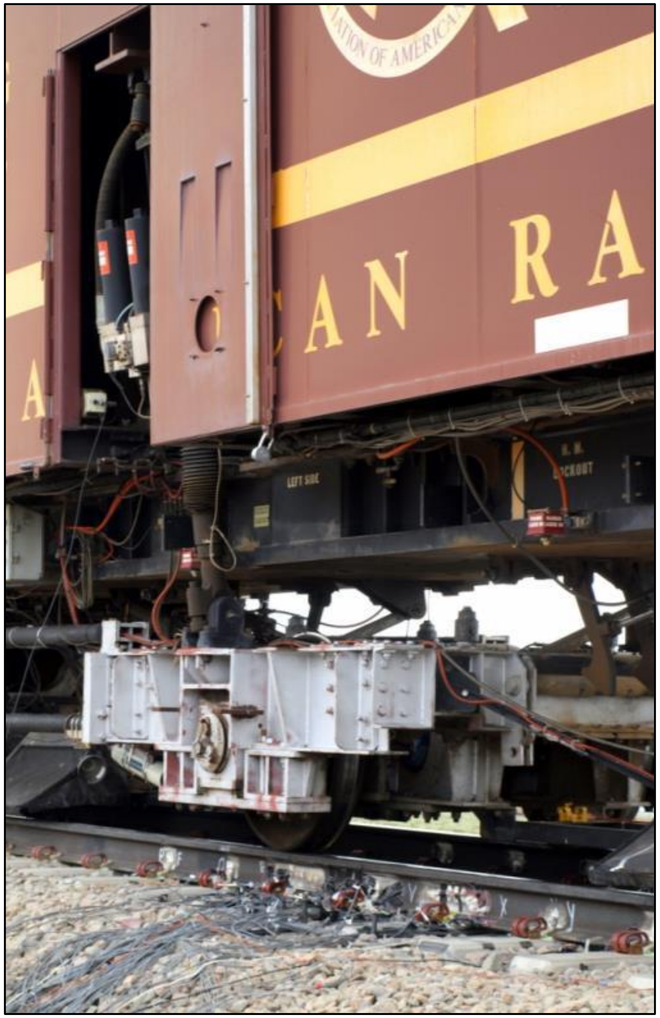
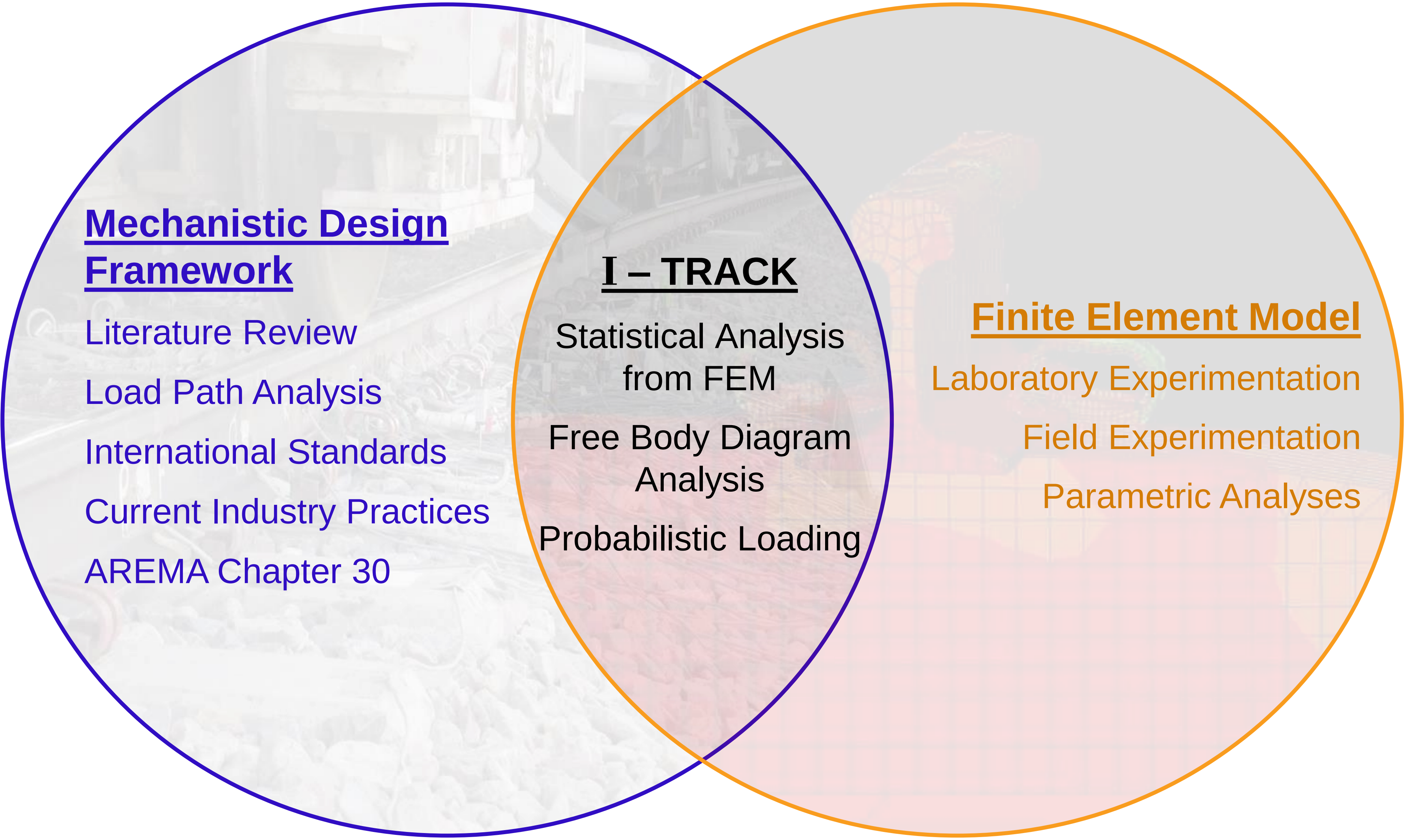
Outline

- RSD Background
- Pressure Distribution Relation to RSD
- Equipment Overview
- Field Data Analysis
  - Load Distribution Progression
  - Contact Areas vs. L/V
  - Rail Seat Load Sensitivity
  - Pressure Comparison
- Developing a New Design Metric
- Conclusions
- Future Work



FRA Tie and Fastener Research Program

Overall Project Deliverables



Current Objectives of Experimentation with Matrix Based Tactile Surface Sensors (MBTSS)

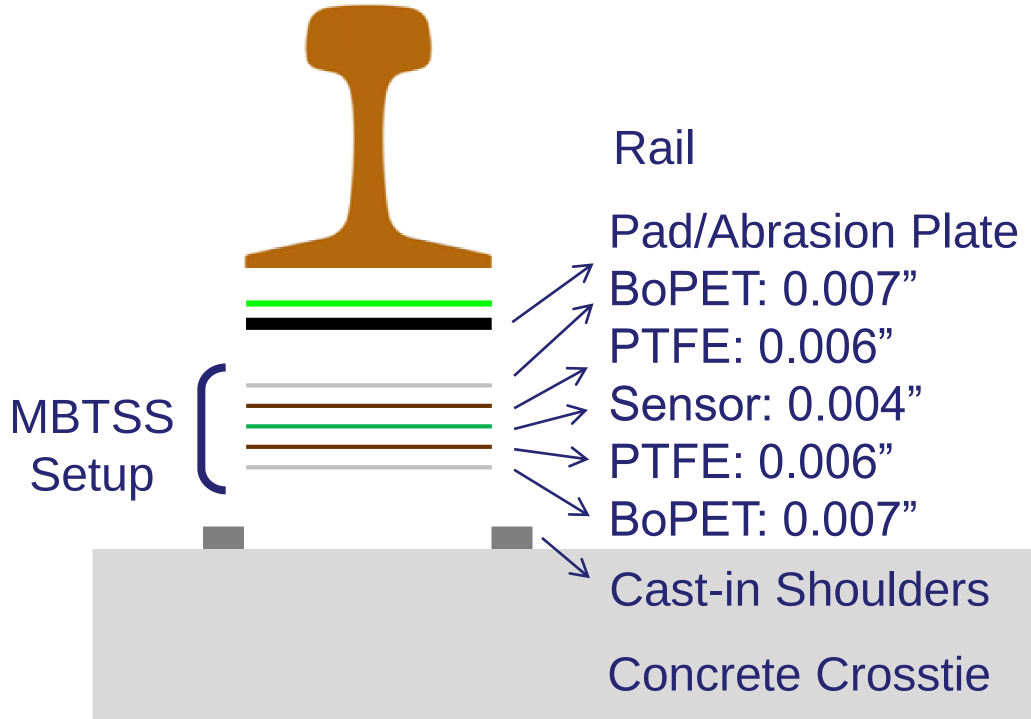
- Compare pressure distribution on rail seats:
  - Under various loading scenarios
  - Under various rail seat support conditions
  - Under various stages of rail seat wear
- Develop design metric for mechanistic evaluation of rail seat load distribution

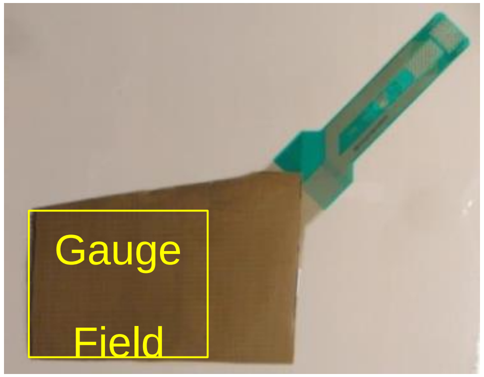
Rail Seat Deterioration (RSD) Background

- Rail Seat Deterioration (RSD) is the degradation of concrete directly underneath the rail pad, resulting in track geometry problems
- Surveys conducted by UIUC report that North American Class I Railroads and other railway infrastructure experts ranked RSD as one of the most critical problems associated with concrete crosstie and fastening system performance
- Potential RSD mechanisms as determined through research at UIUC:
  - Abrasion
  - Crushing
  - Freeze-thaw
  - Hydraulic pressure cracking
  - Hydro-abrasive erosion

Equipment Preparation and Protection

- Sensors trimmed to fit rail seat
- BoPET and PTFE layered on each side of sensor to protect from shear and puncture damage
- Plastic sleeves and plastic bags to protect sensor tabs and handles from puncture and debris

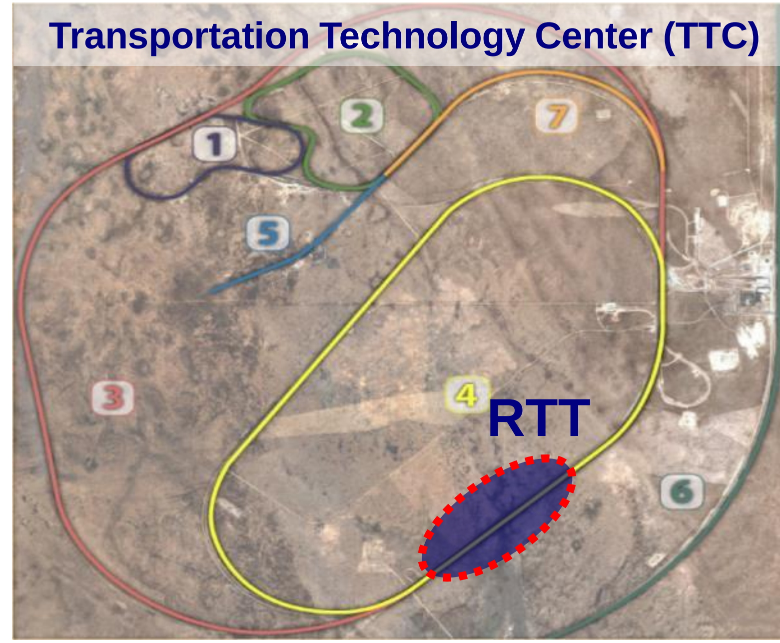




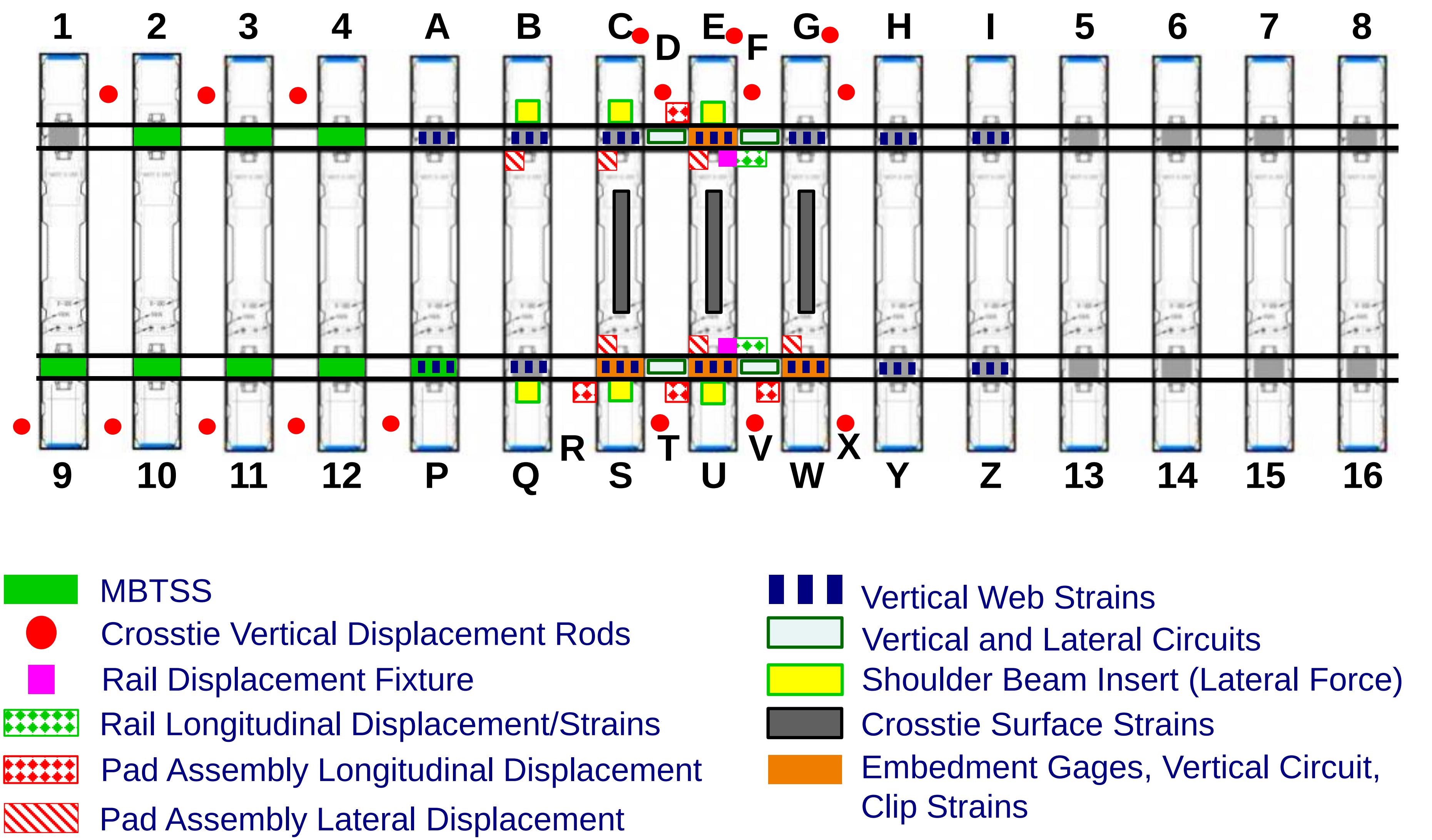
Plan View of Sensor and Protective Layers

Field Experiment Program

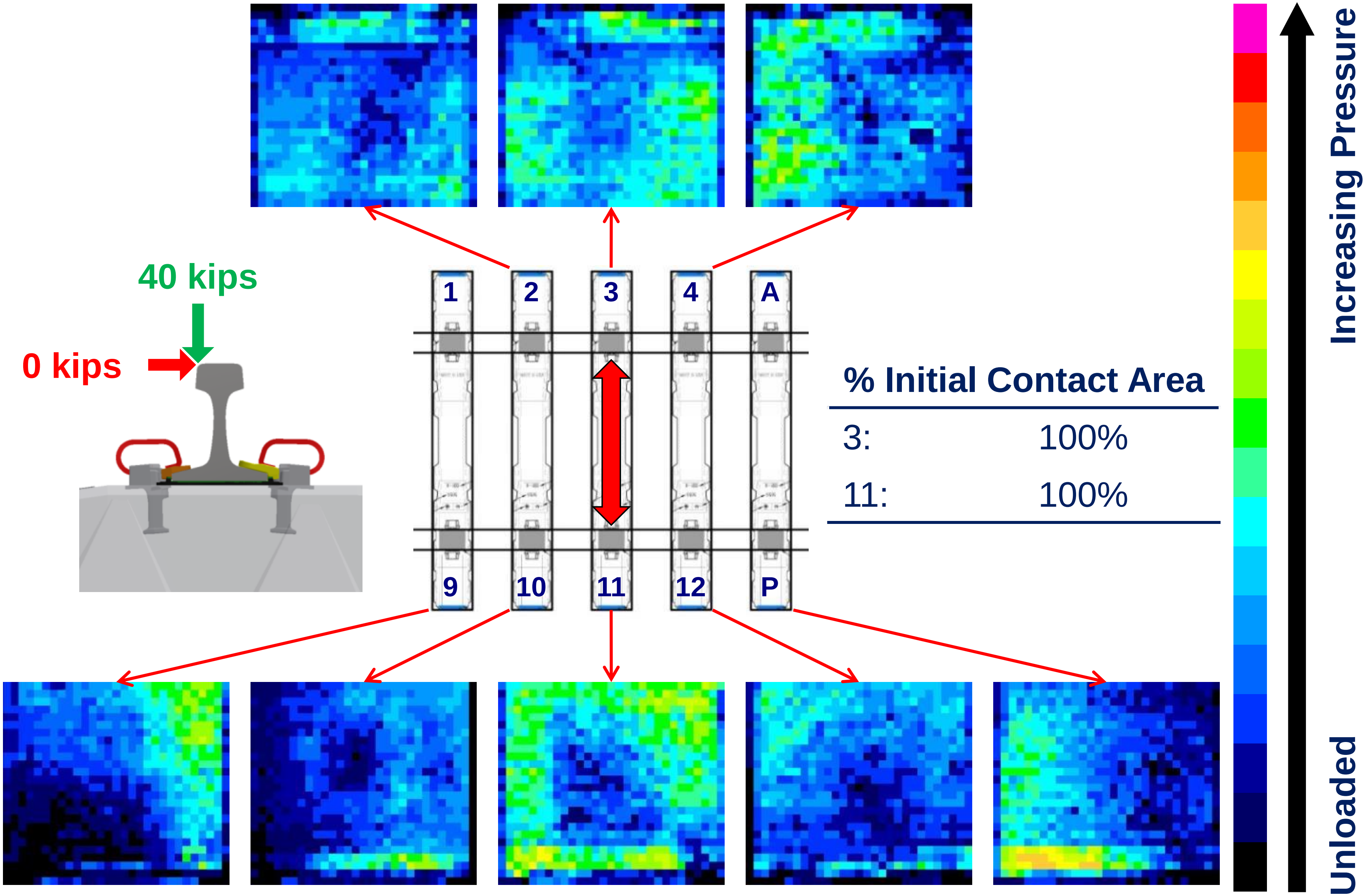
- **Objective:** Analyze the distribution of forces through the fastening system and impact on components relative displacements
- **Location:** Transportation Technology Center (TTC) in Pueblo, CO
  - **Railroad Test Track (RTT):** tangent section with Safelok I fasteners
- **Instrumentation:**
  - MBTSS deployed to capture wheel load distribution, behavior of rail seats on the same crosstie, and effect of crosstie support conditions
  - Potentiometers to capture crosstie vertical displacement
- **Loading:** Track Loading Vehicle (TLV) used to apply static loads to the track structure
  - Modified railcar with instrumented wheelset on hydraulic actuators



May 2013 Field Instrumentation

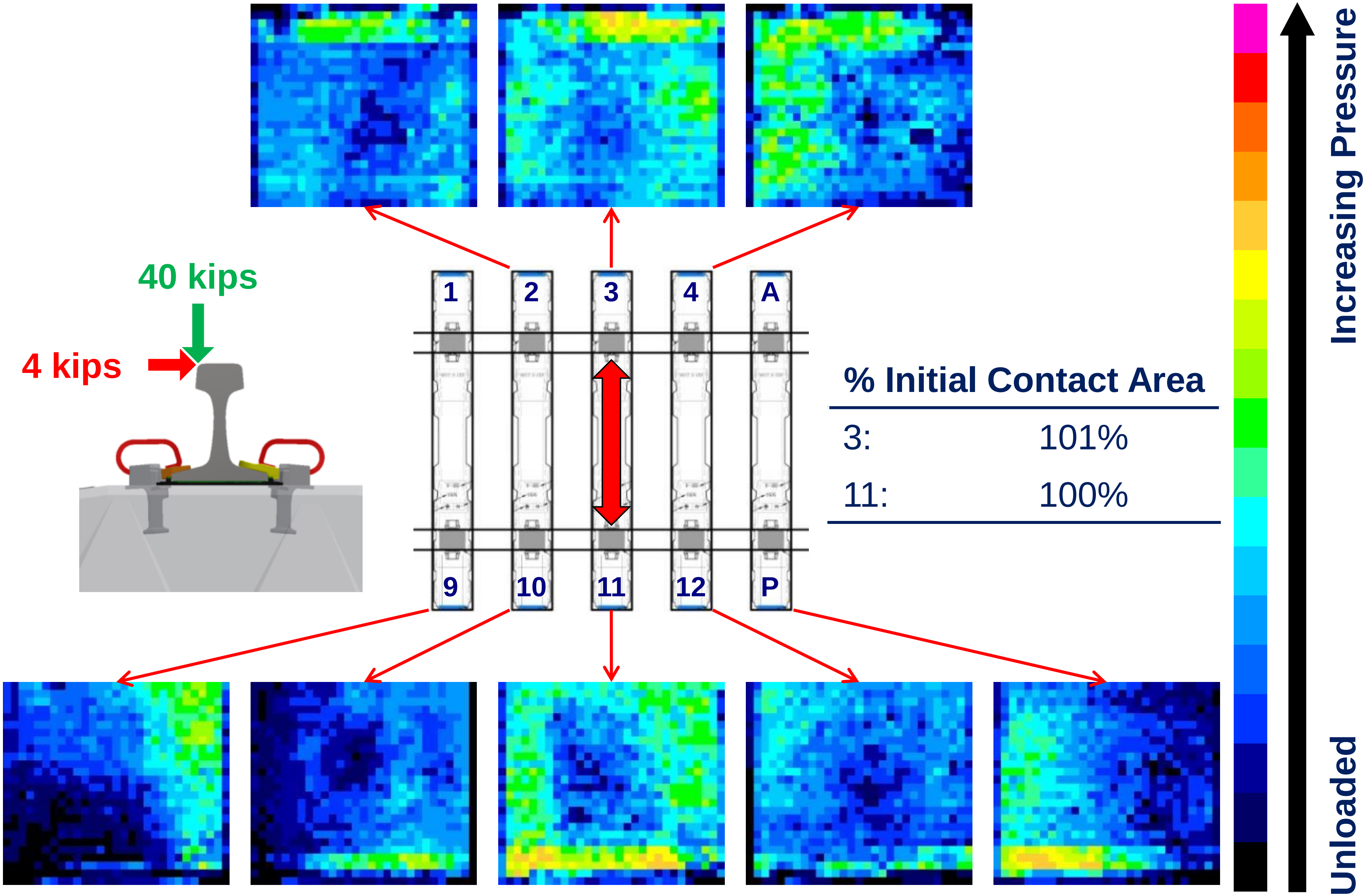


Rail Seat Load Concentration



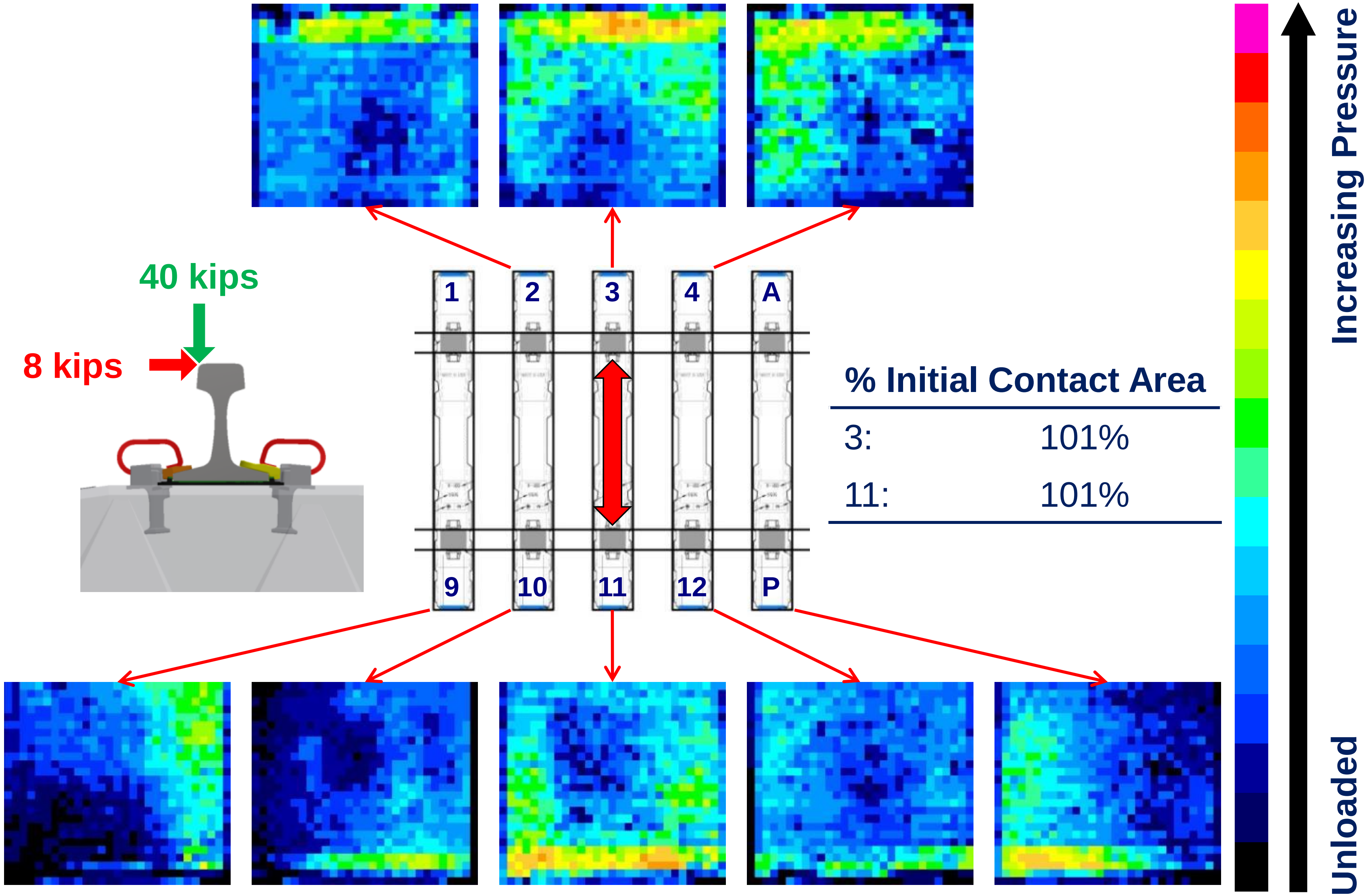
% Initial Contact Area	
3:	100%
11:	100%

Rail Seat Load Concentration



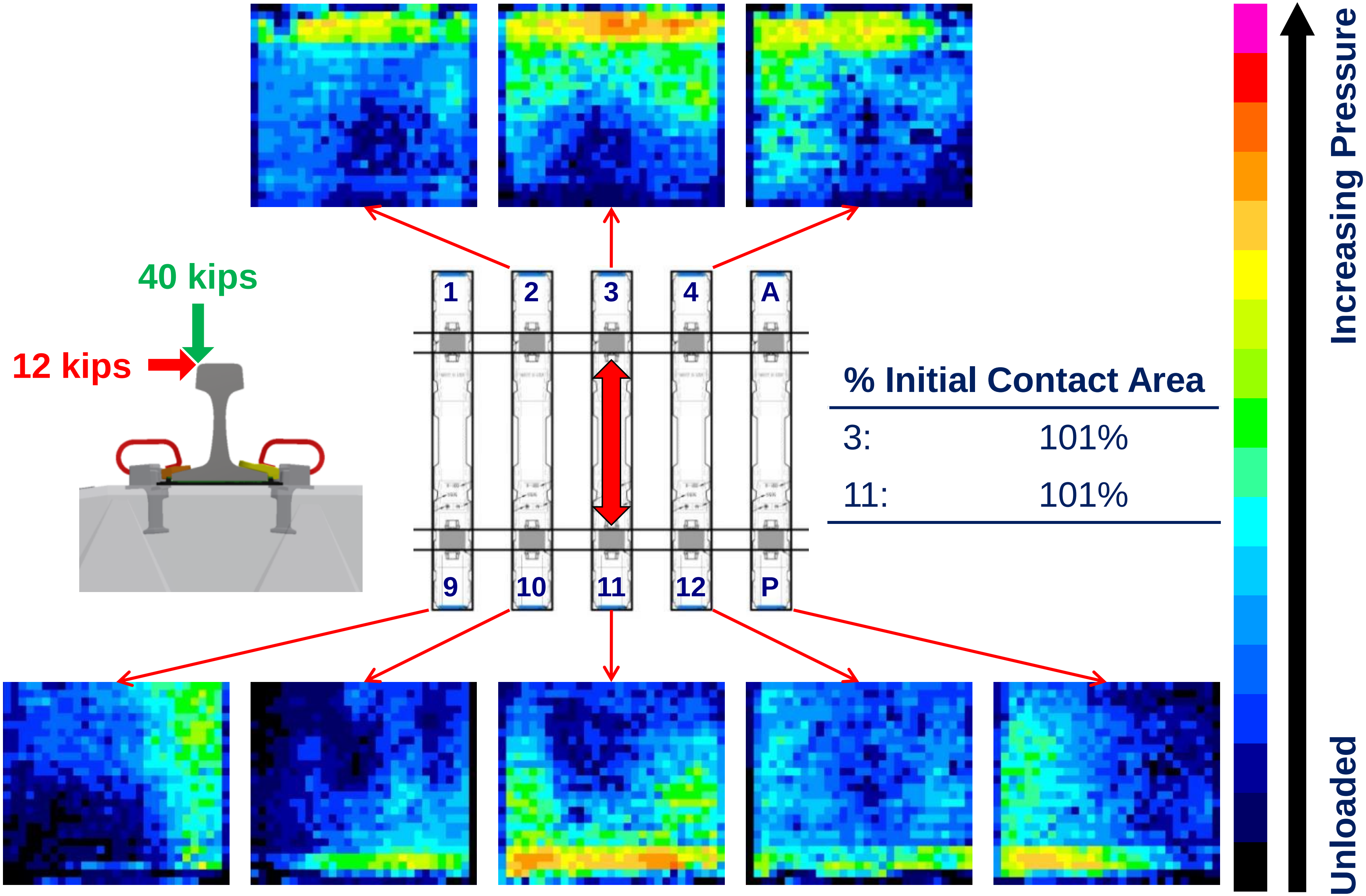
% Initial Contact Area	
3:	101%
11:	100%

Rail Seat Load Concentration



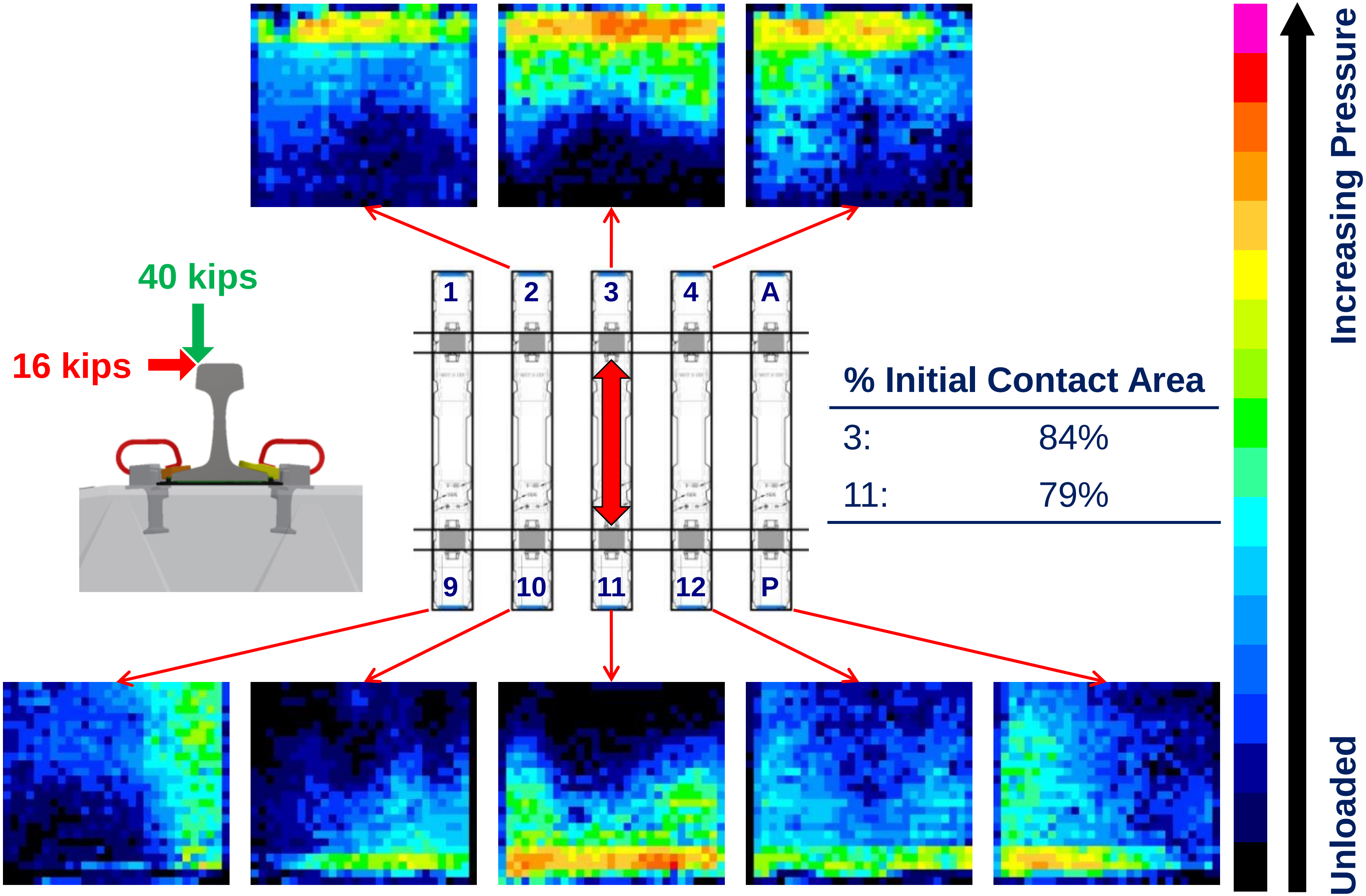
% Initial Contact Area	
3:	101%
11:	101%

Rail Seat Load Concentration

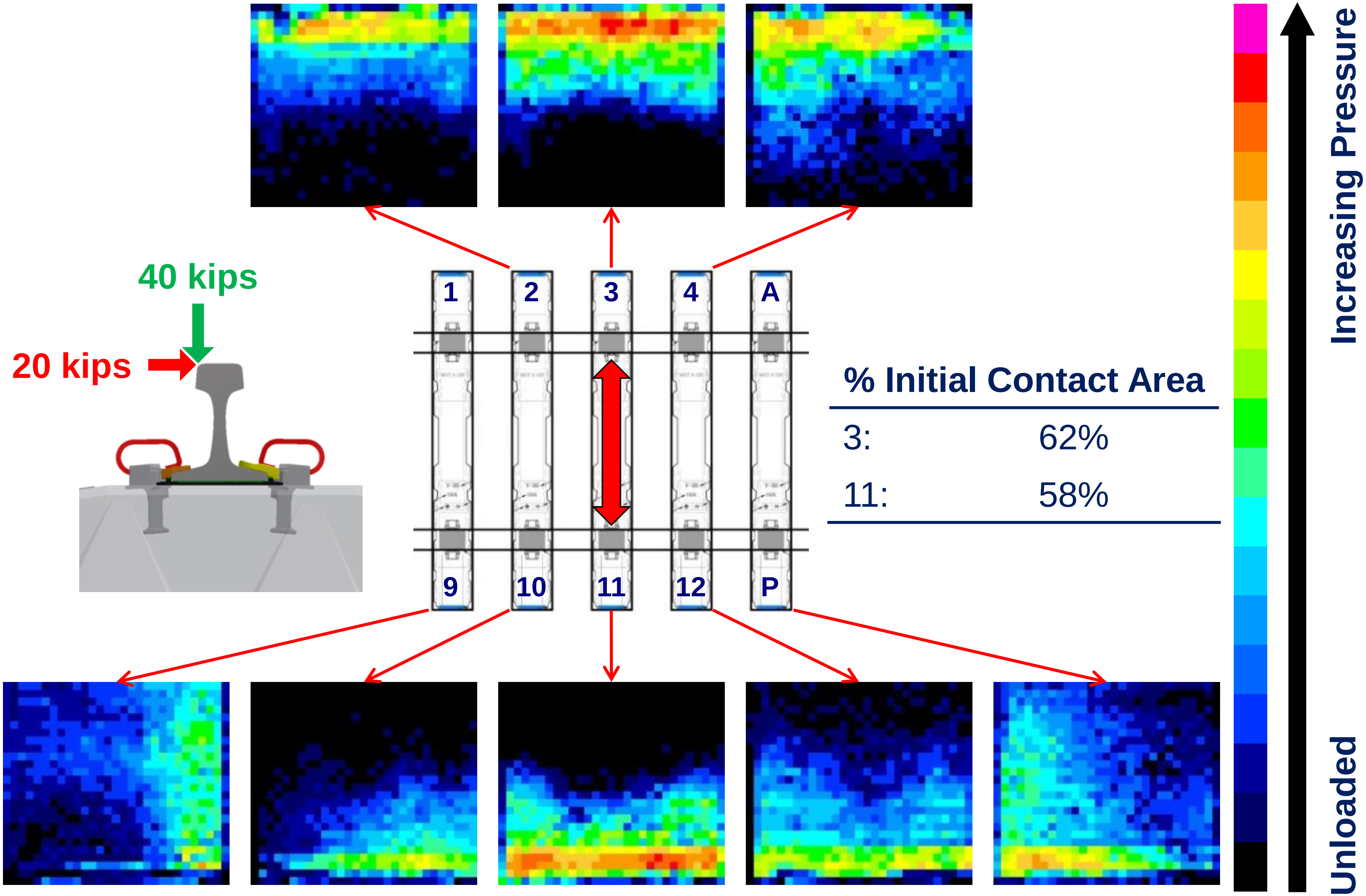


% Initial Contact Area	
3:	101%
11:	101%

Rail Seat Load Concentration

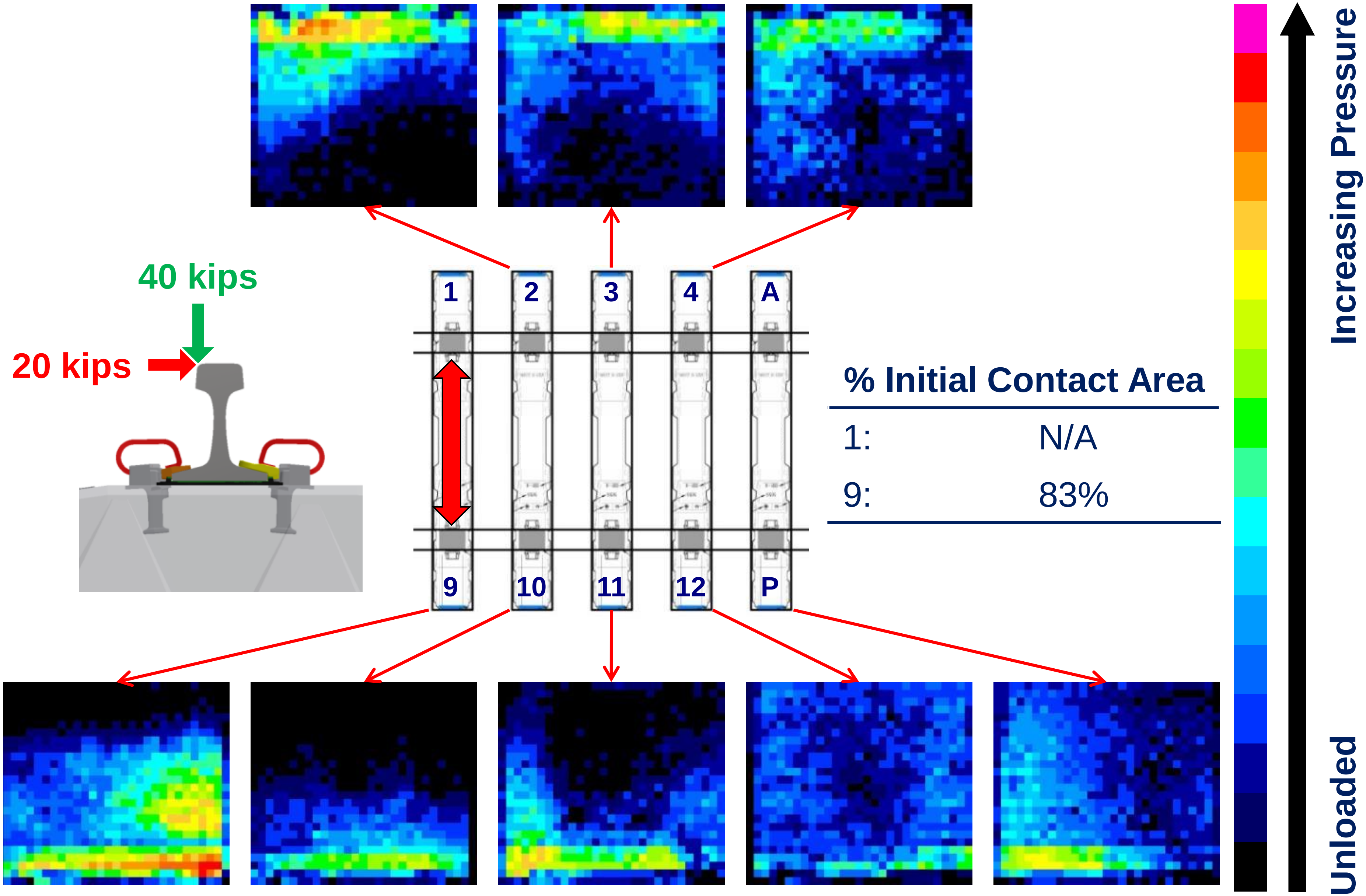


Rail Seat Load Concentration



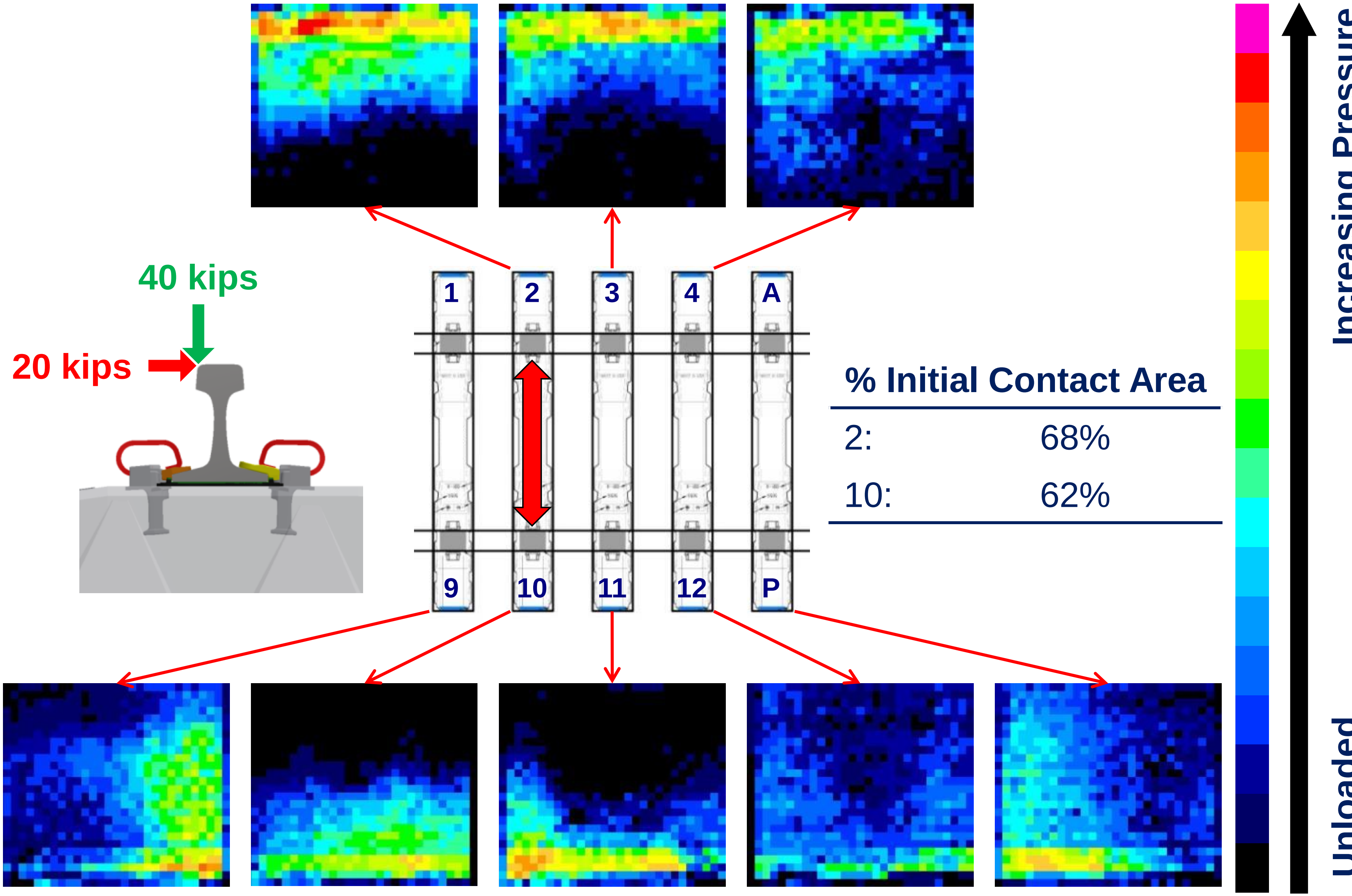
% Initial Contact Area	
3:	62%
11:	58%

Nonuniform Rail Seat Load Response



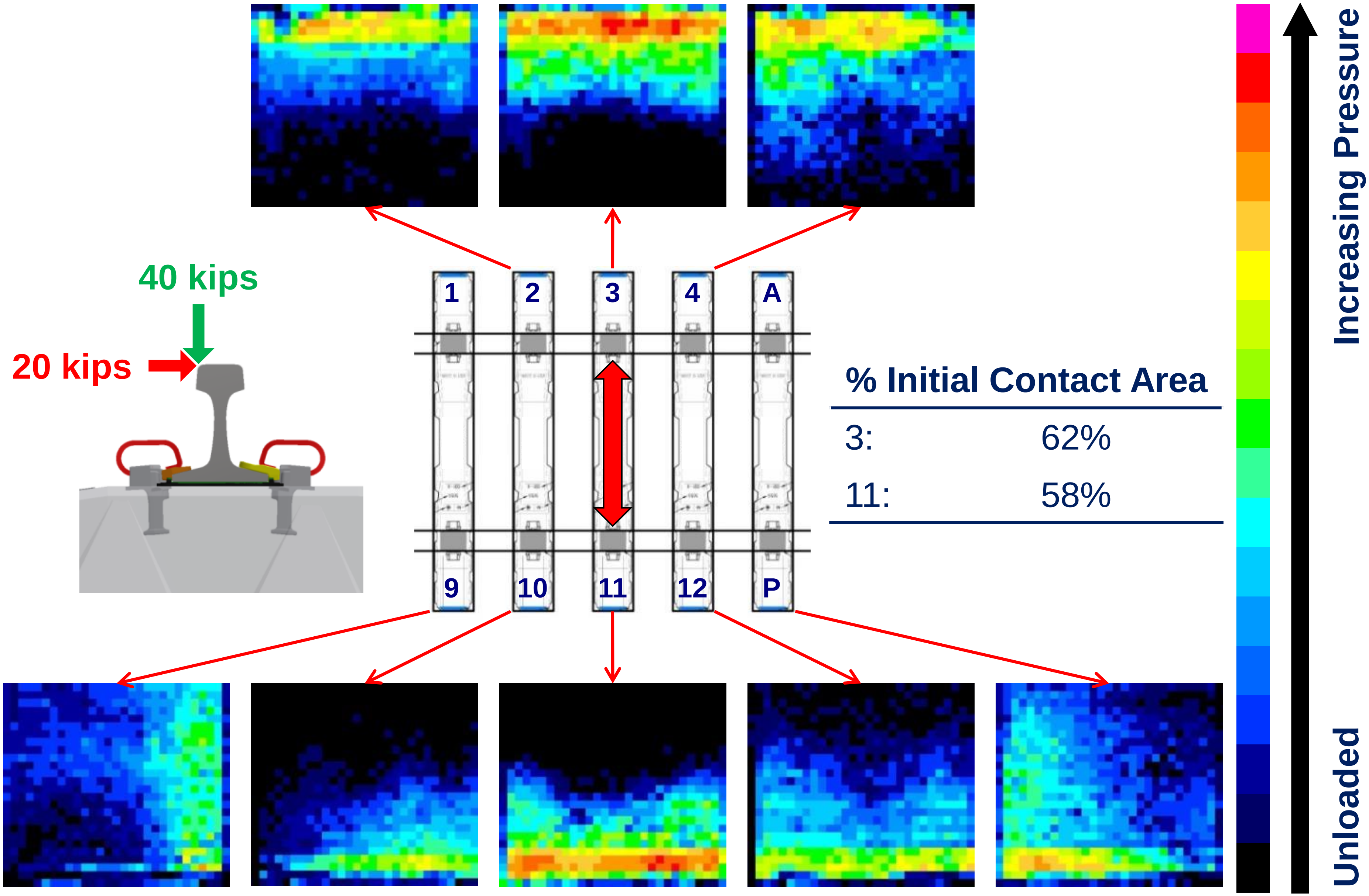
% Initial Contact Area	
1:	N/A
9:	83%

Nonuniform Rail Seat Load Response



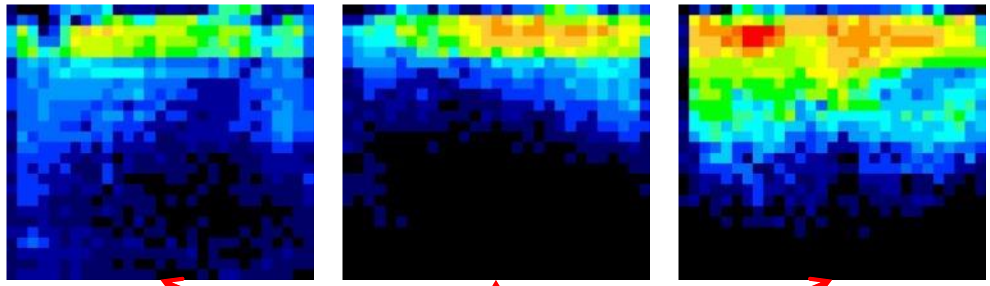
% Initial Contact Area	
2:	68%
10:	62%

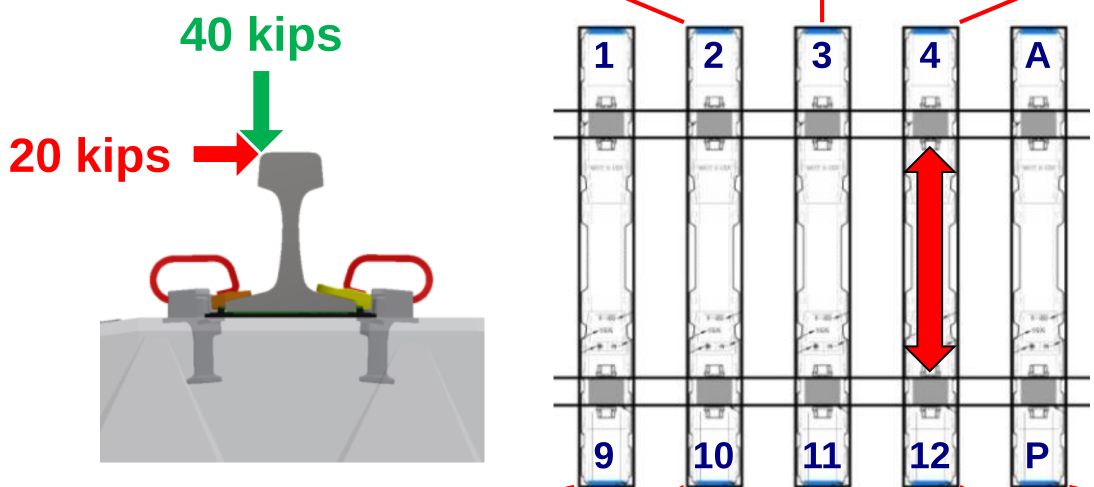
Nonuniform Rail Seat Load Response



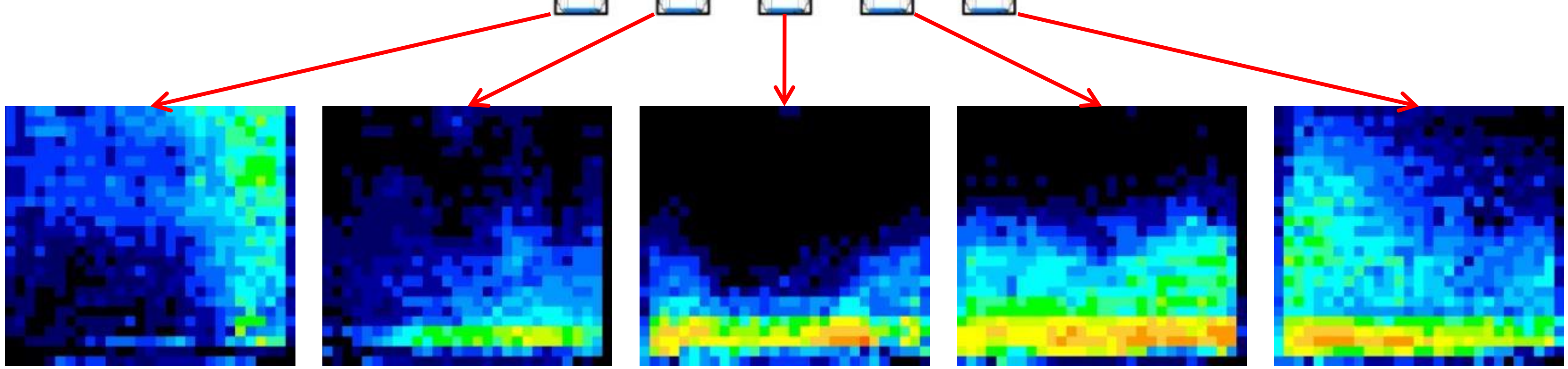
% Initial Contact Area	
3:	62%
11:	58%

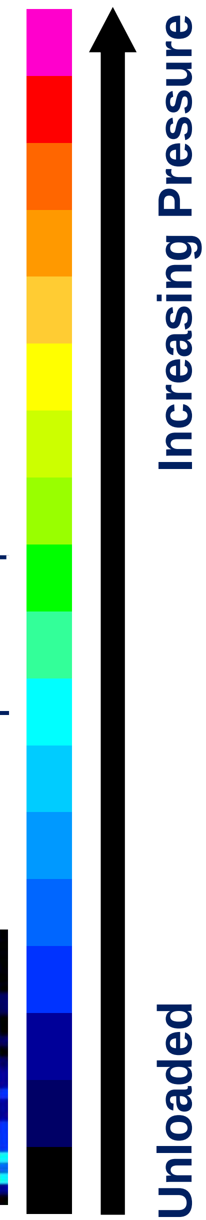
Nonuniform Rail Seat Load Response



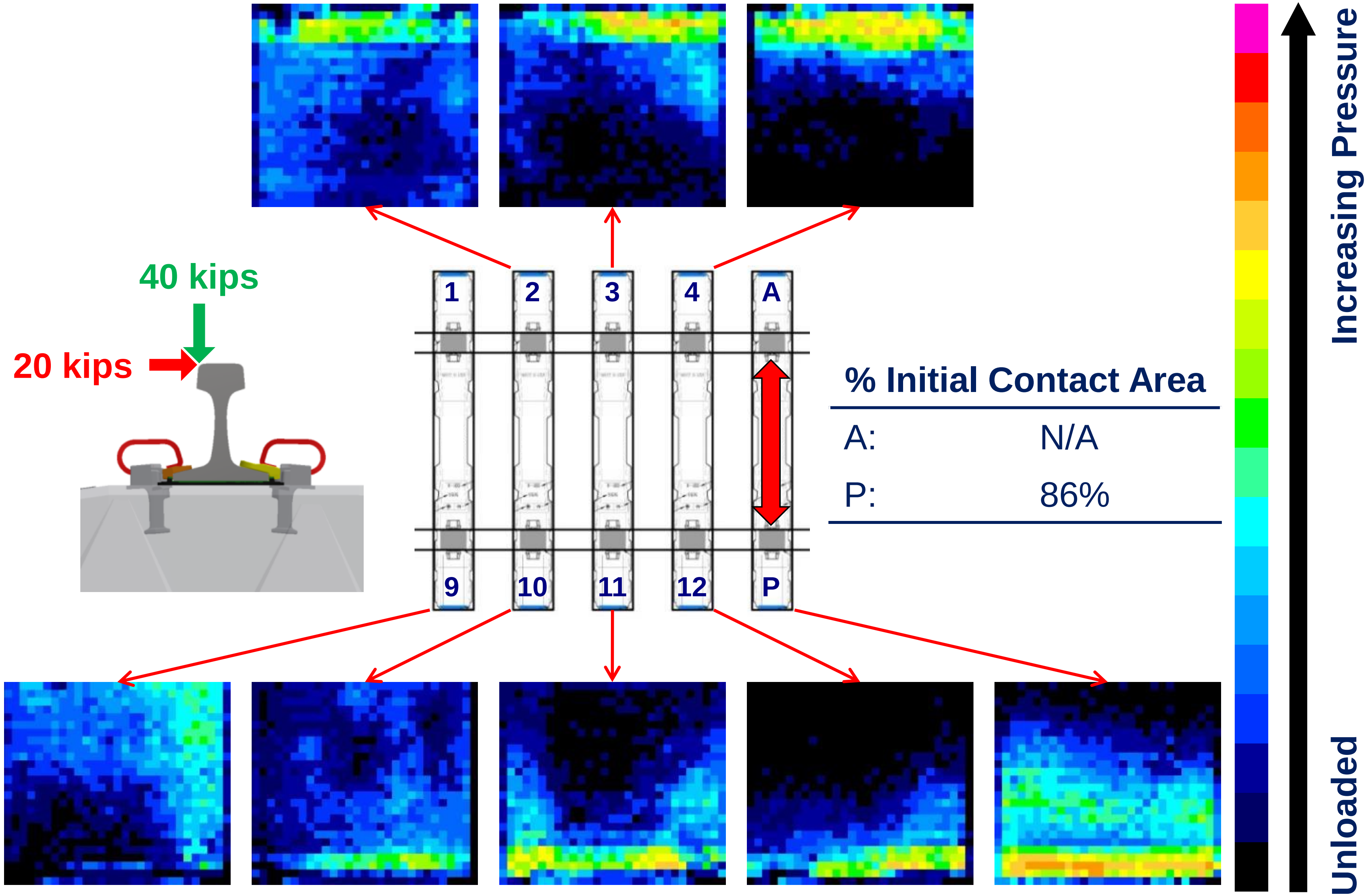


% Initial Contact Area	
4:	73%
12:	69%



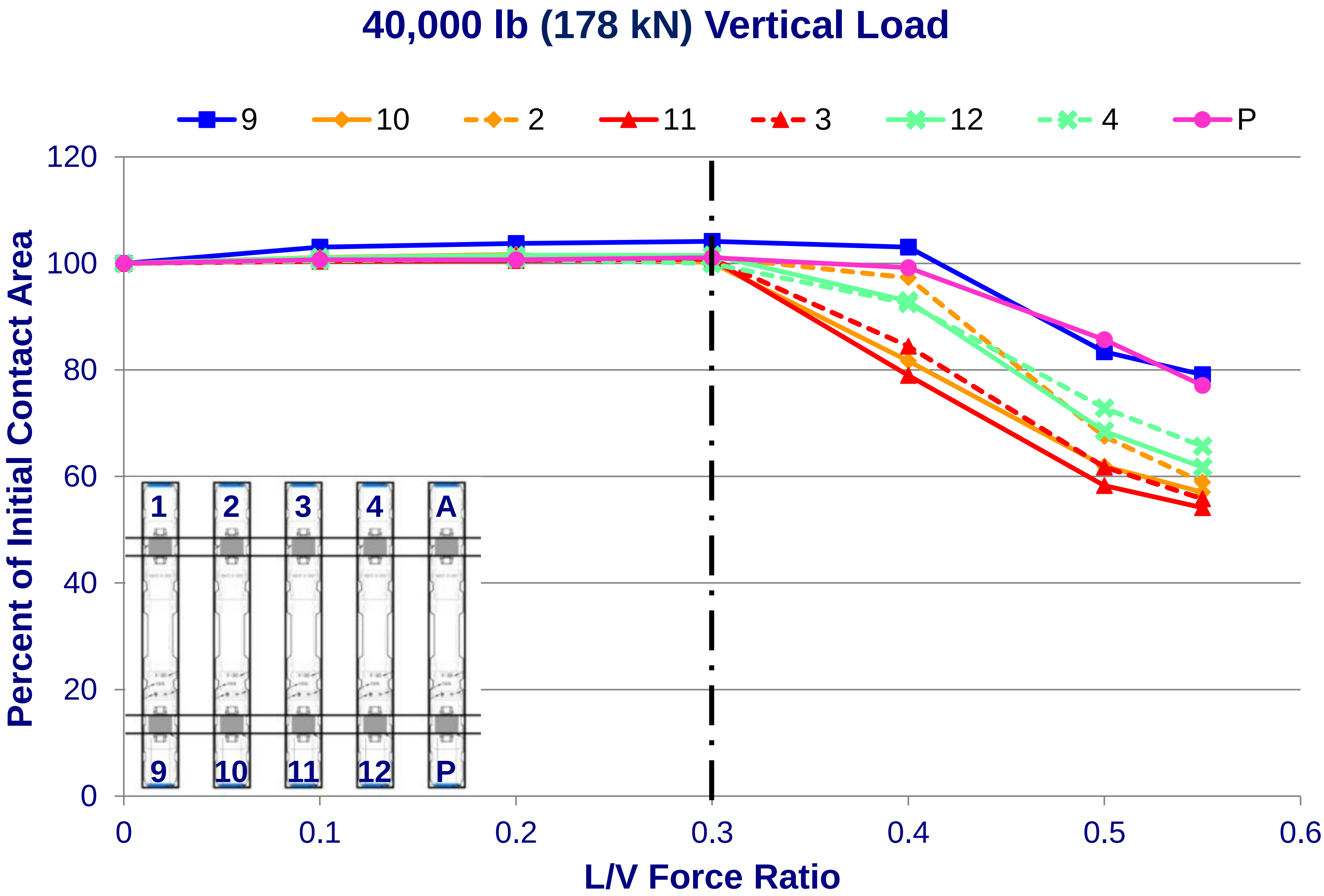


Nonuniform Rail Seat Load Response

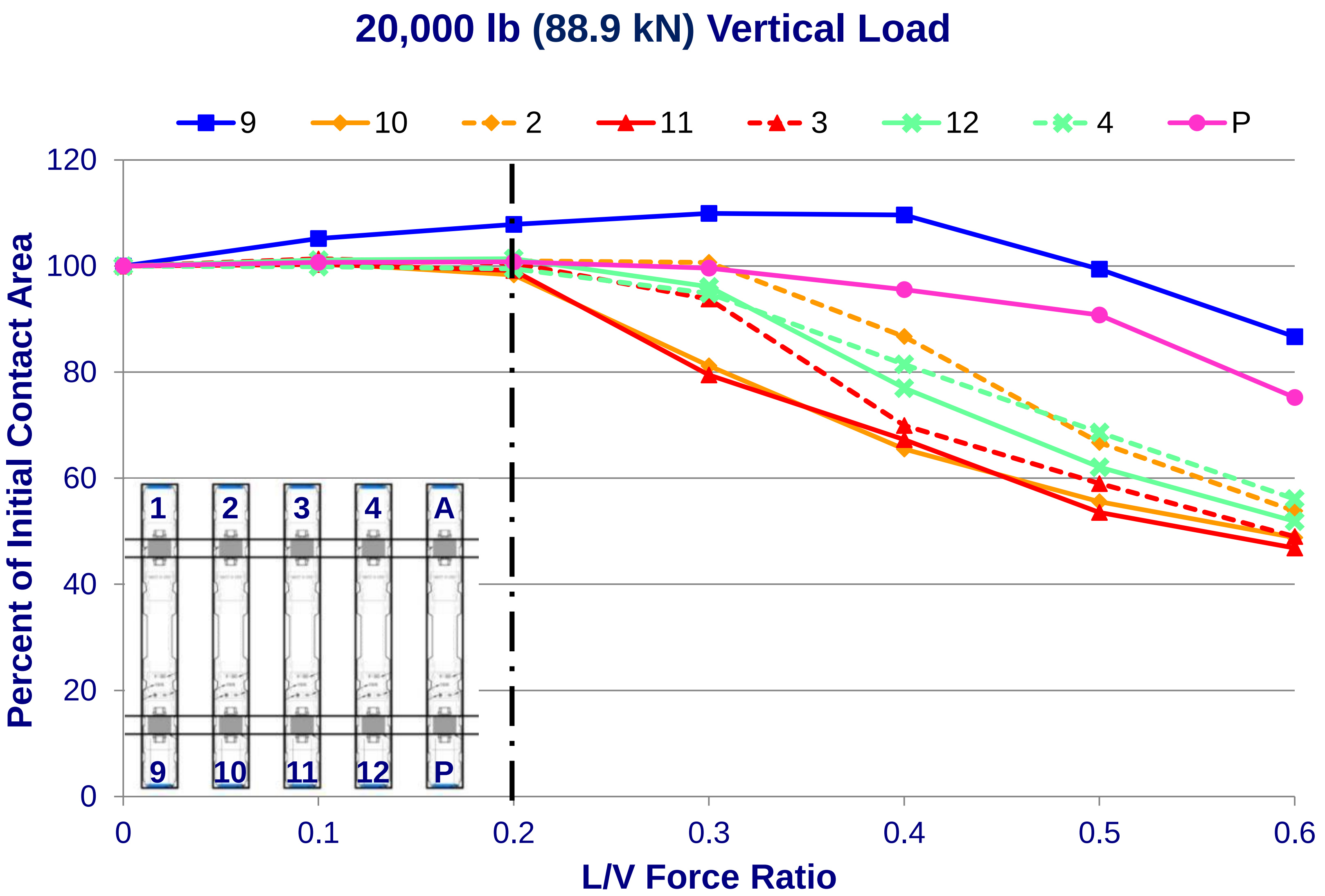


% Initial Contact Area	
A:	N/A
P:	86%

TLV Varying Lateral Load at RTT

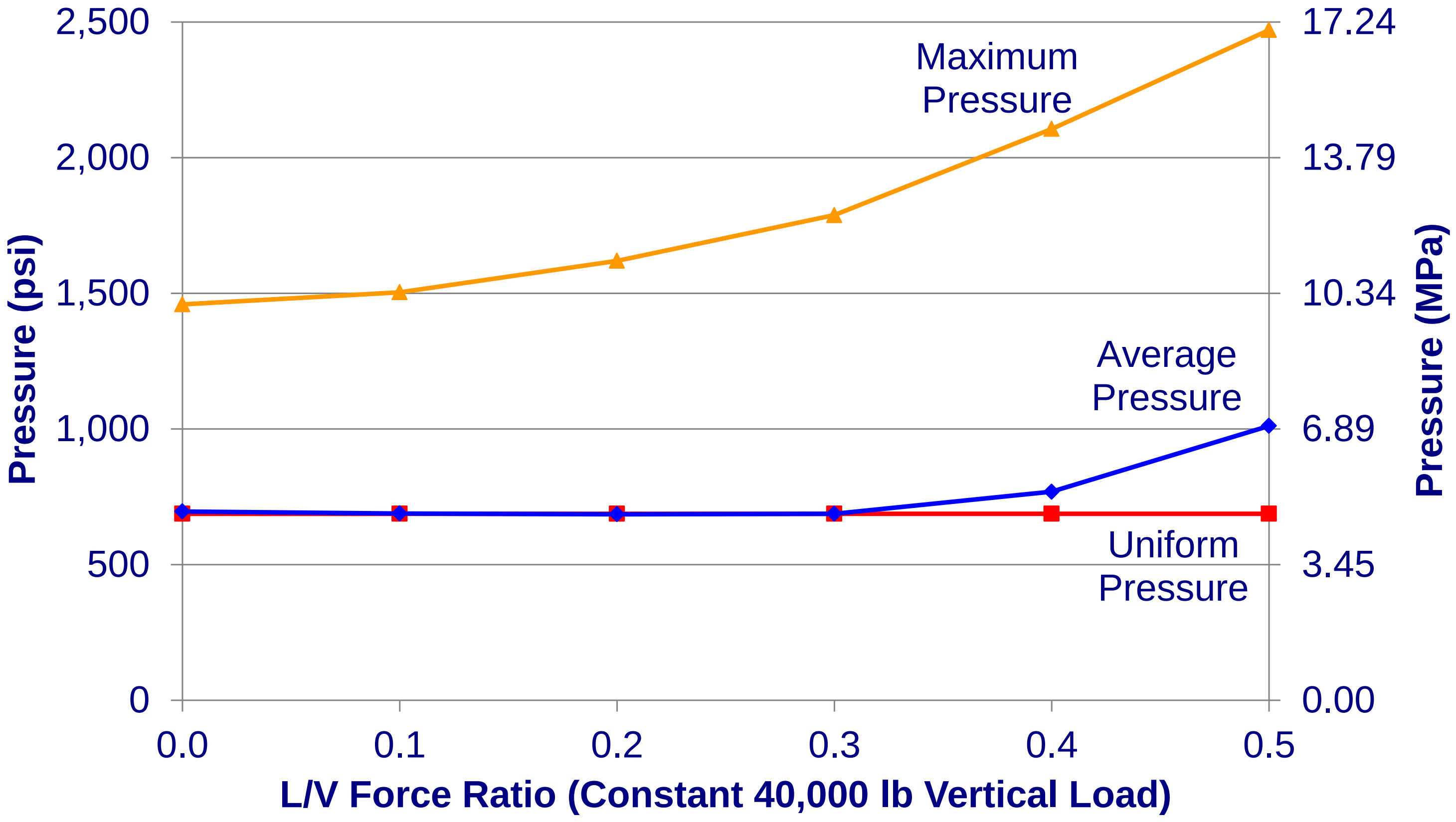


TLV Varying Lateral Load at RTT

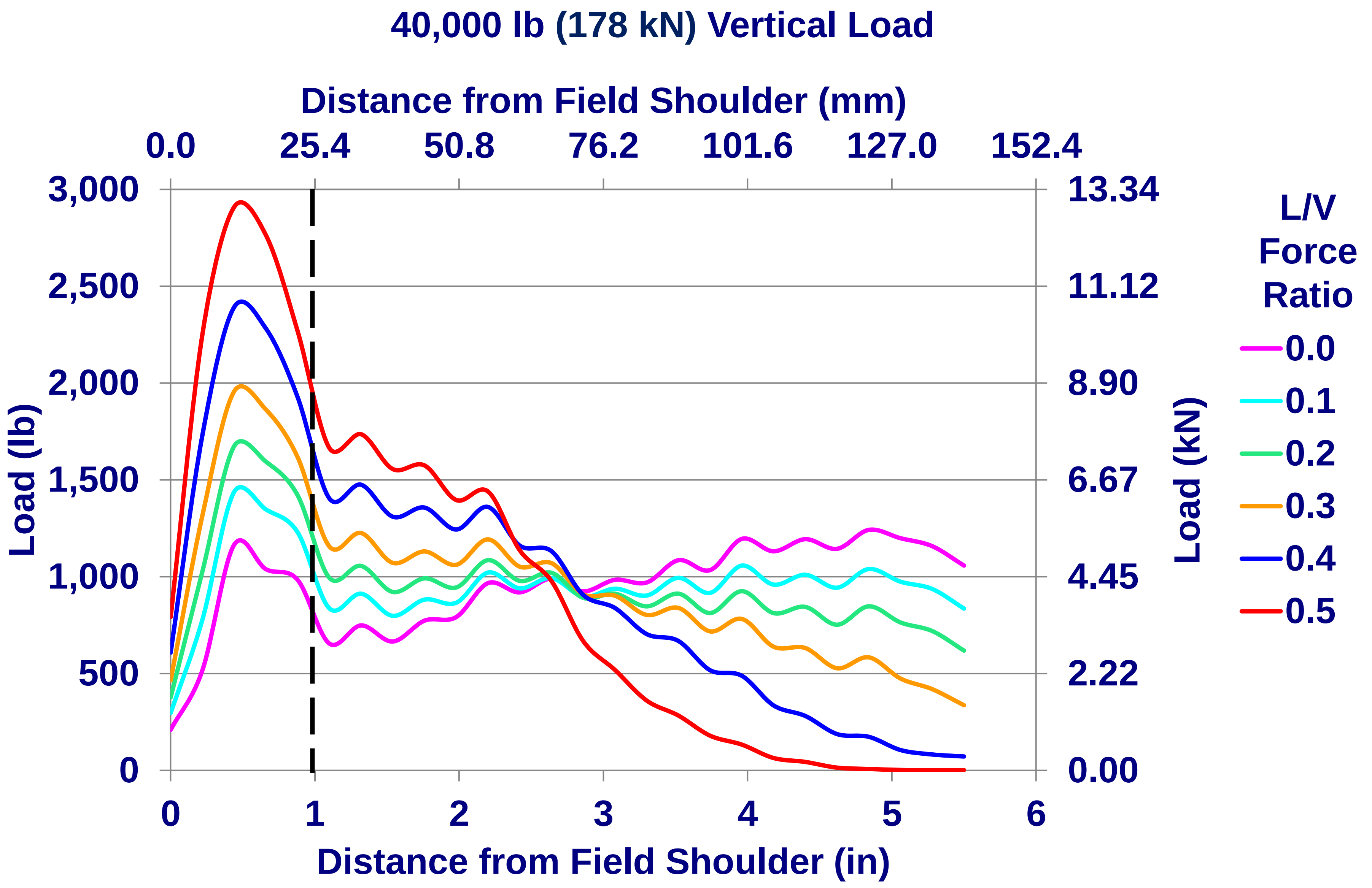


Effect of L/V Force Ratio on Pressure

- Current design practice is to assume a uniformly distributed rail seat load, even under high L/V force ratios.
- Increased pressure changes abrasion characteristics
- Introduction of fines may concentrate load further causing local crushing

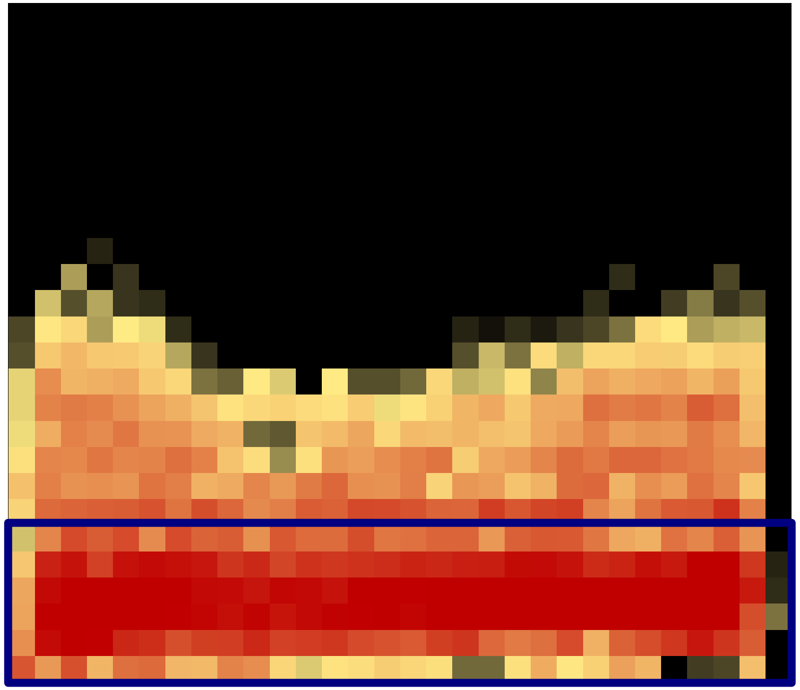


Concentration of Rail Seat Load



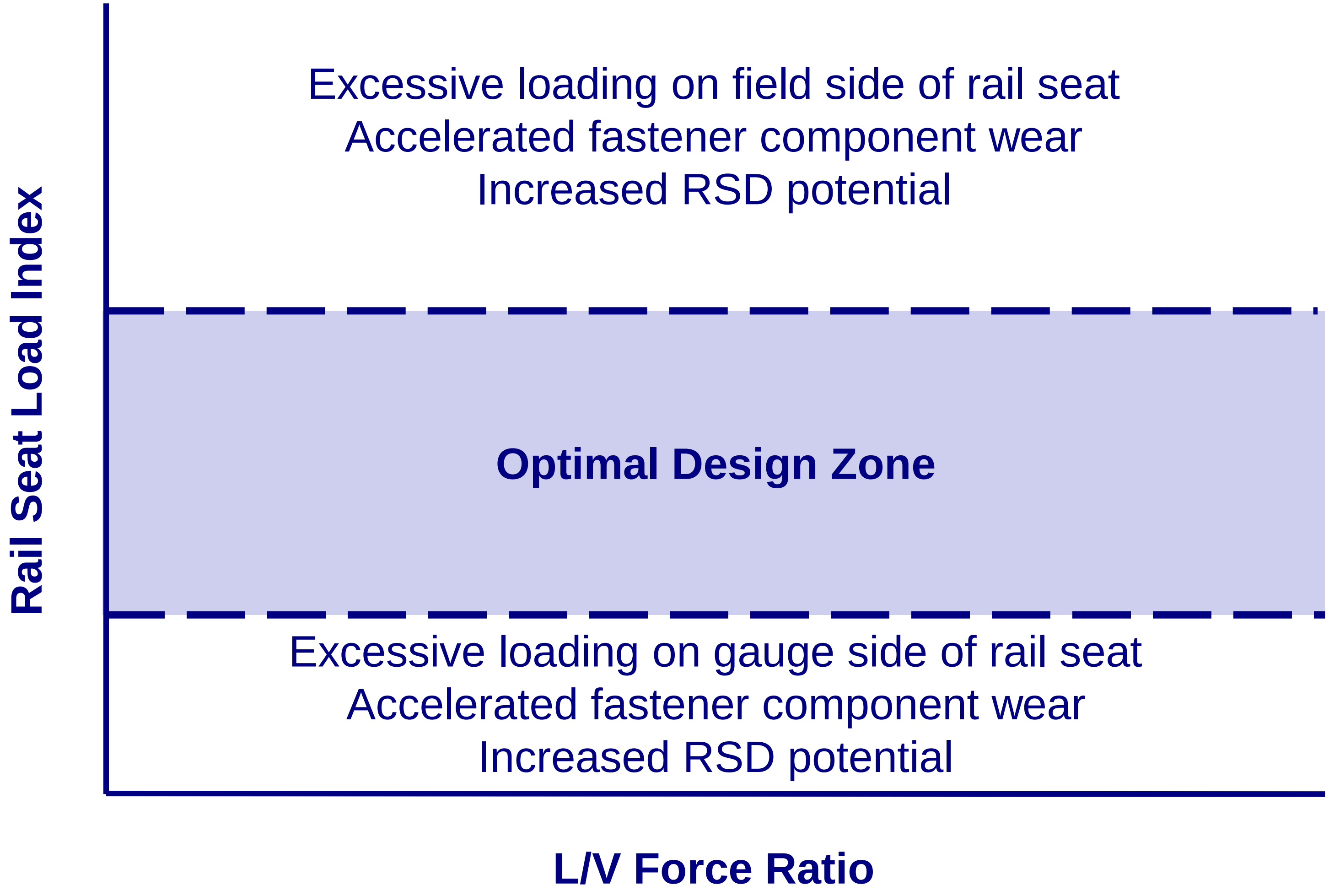
Definition of Rail Seat Load Index (RSLI)

- A quantifiable design value which describes the sensitivity of the rail seat load distribution to changes in the L/V force ratio
- Rail Seat Load Index (RSLI) is defined as the percent of total rail seat load imparted onto a critical region of the rail seat, defined as the area of the rail seat not more than 1 inch (25.4 mm) from the field side shoulder, normalized to a theoretical, uniform distribution.

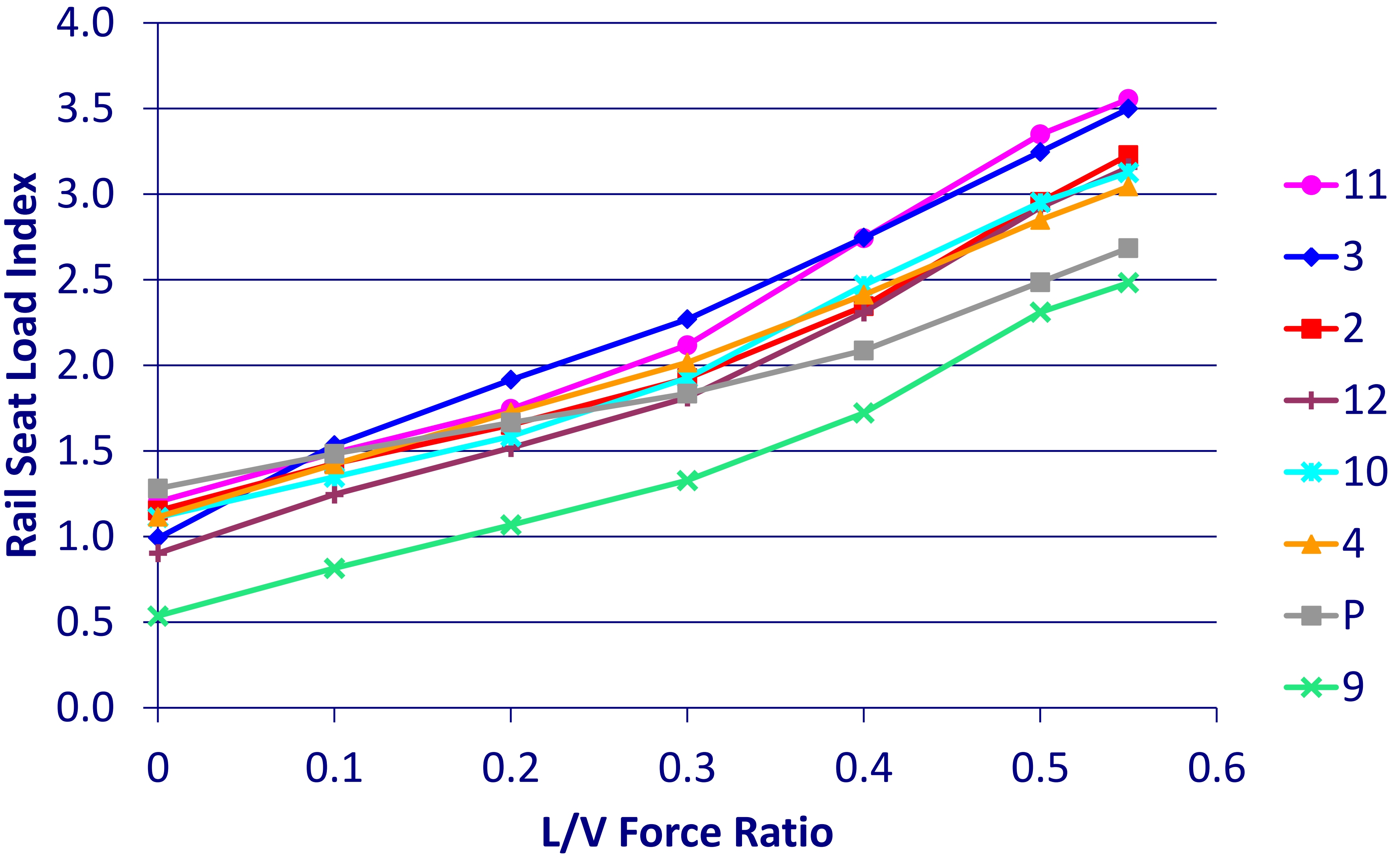


$$RSLI = \frac{\frac{[Load\ in\ Critical\ Area]}{[Total\ Rail\ Seat\ Load]}}{\frac{1}{6}} = 6 * \frac{[Load\ in\ Critical\ Area]}{[Total\ Rail\ Seat\ Load]}$$

Theoretical Optimized RSLI



Effect of L/V on RSLI



Conclusions

- Rail seat load distribution is highly nonuniform, even between adjacent crossties
- Rail base rotation at "threshold" L/V force ratio can lead to significant load concentration on field side of rail seat
  - Loss of up to 54% of initial contact area
- The behavior of the load distribution under increasing L/V force ratios is affected by the magnitude of vertical load
- Average and maximum pressure are affected by reduction of contact area
  - 71% increase in average pressure
  - 98% increase in maximum pressure
- RSLI provides a mechanistic evaluation of rail seat load sensitivity
- Lateral force plays a significant role in RSD mechanisms because of its effect on contact area

Future Work

- How did crosstie support conditions affect wheel and rail seat load distributions in the field?
  - Can we understand the effect of crosstie support conditions by controlling under-tie ballast stiffness?
- How are “threshold” L/V and vertical load related?
- Can we correlate load nonuniformity to RSD?
  - How does RSLI change with fastening system wear?
  - Can RSLI be correlated to RSD or specific RSD mechanisms?

Acknowledgements

U.S. Department of Transportation
Federal Railroad Administration

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- Funding for this research has been provided by the
  - Amsted RPS / Amsted Rail, Inc.
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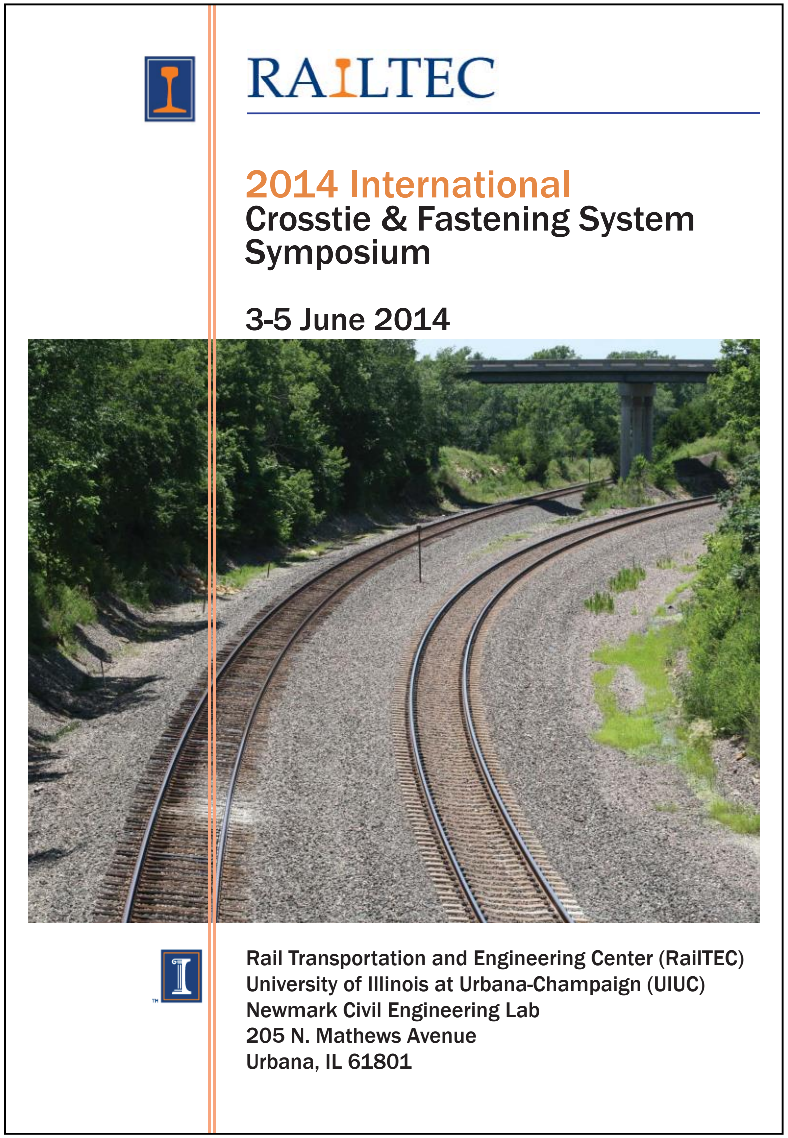
  - BNSF Railway
  - National Railway Passenger Corporation (Amtrak)
  - Amsted RPS / Amsted Rail, Inc.
  - GIC Ingeniería y Construcción
  - Hanson Professional Services, Inc.
  - CXT Concrete Ties, Inc., LB Foster Company
  - TTX Company
- UIUC – Zachary Ehlers, Doug Capuder, Marc Killion, and Timothy Prunkard

Hosting 2014 International Crosstie and Fastening System Symposium

- Co-organized by: **AREMA Committee 30 (Ties), Railway Tie Association (RTA)**
- ***Three day conference with presentations, discussions, and a technical tour***
- **Focus → state of the art in timber, concrete, and composite crosstie and fastening system design, performance, research, modeling, and inspection**
- **3 - 5 June 2014** – Sessions on UIUC campus
  4 June 2014 – Technical tour to UIUC Research and Innovation Laboratory (RailL) and voestalpine Nortrak facility in Decatur, IL
- Strong domestic and international participation; addressing topics including:
  - *Laboratory and Field Testing*
  - *Component and System Modeling*
  - *Automated Inspection Technologies*



Questions & Comments

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