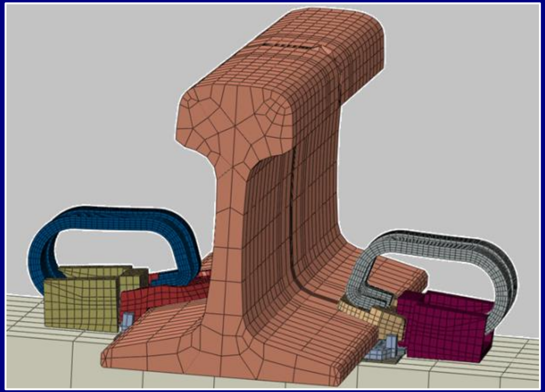
# Mechanistic Design Approach for Concrete Crossties and Fastening System





**FRA Concrete Crosstie & Fastener BAA – Industry Partners Meeting**

**Incline Village, NV**

**7 October 2013**

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U.S. Department of Transportation
Federal Railroad Administration

RAILTEC
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

# Outline

- Background
- Definition
- Methodology
- Deliverables
  - Framework
  - Finite Element (FE) Model
  - Simplified Analytical Tool (I-TRACK)
- Path Forward

# Background on current design recommendations

- Based primarily on empirical approaches
- Many critical design parameters are not specified
- Representative input loads and loading distribution factors are not a clear part of the design methodology, particularly in the lateral direction
- Lack of clarity behind some of the critical design limits
- Level of detail is inconsistent throughout the design recommendations
- Improvements to current design process are difficult to implement without understanding complex loading environment

# Mechanistic Design Definition

- Approach based on loads measured in track structure and properties of materials that will withstand or transfer them
- Uses responses (e.g. contact pressure, relative displacement) to optimize component geometry and materials requirements
- Based on measured and predicted response to load inputs that can be supplemented with practical experience
- Requires thorough understanding of load path and distribution
- Allows load factors to be used to include variability due to location and traffic composition
- Used in other engineering industries (e.g. pavement design, structural steel design)

# Overall Project Deliverables

## Mechanistic Design Framework

- Literature Review
- Load Path Analysis
- International Standards
- Current Industry Practices
- AREMA Chapter 30

## I – TRACK

- Statistical Analysis from FEM
- Free Body Diagram Analysis
- Probabilistic Loading

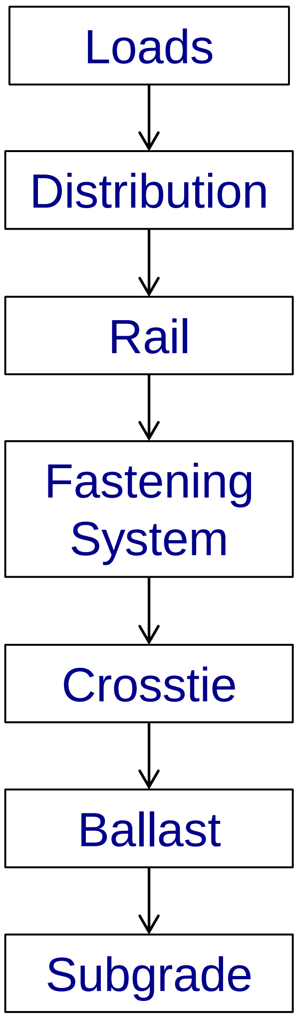
## Finite Element Model

- Laboratory Experimentation
- Field Experimentation
- Parametric Analyses

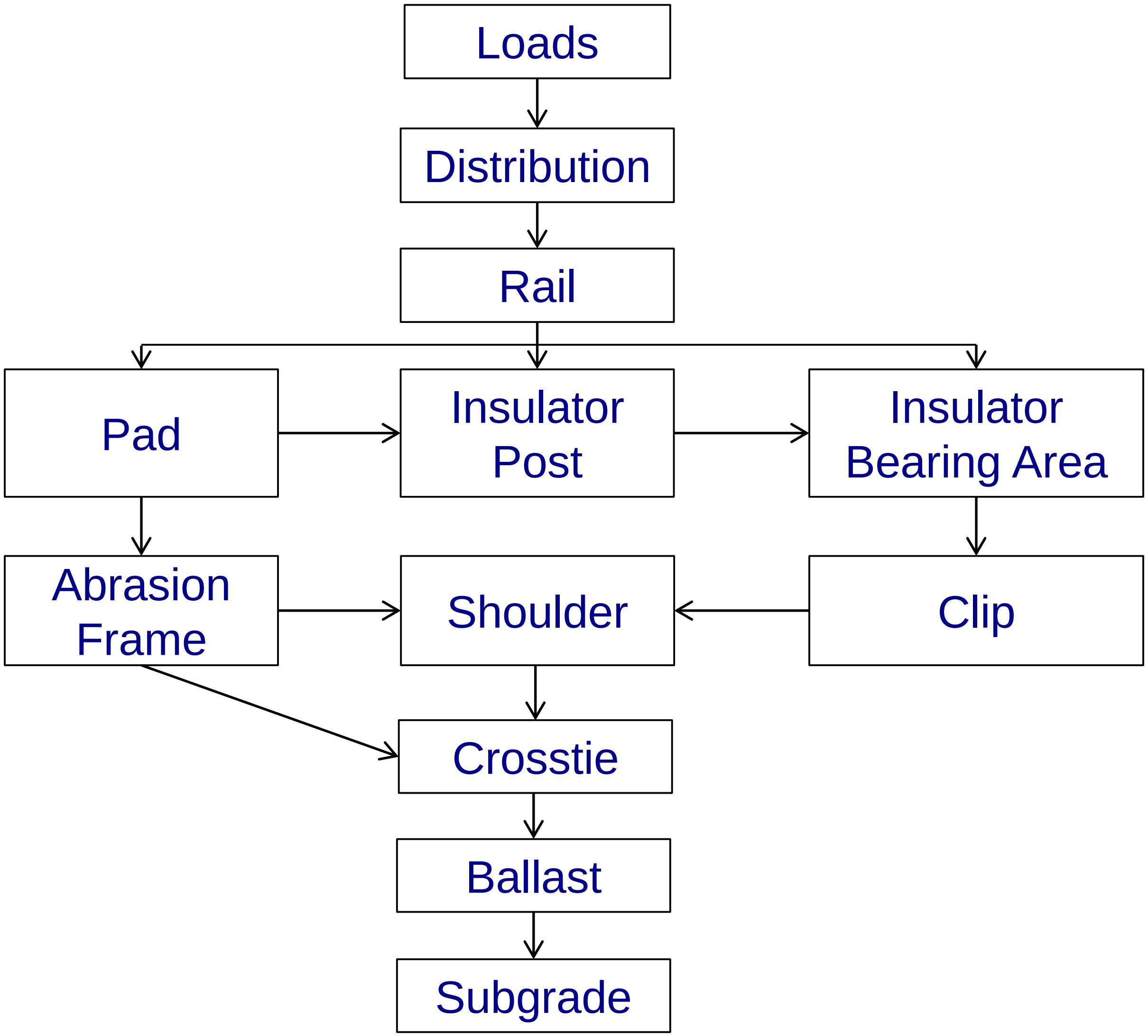
# Role of Deliverables

| Deliverable | Level of Sophistication | Ease of Use | Adaptability | Final Objectives | Timeframe |
|---|---|---|---|---|---|
| **Framework** | Low | Medium | High | Guide track system and component design toward mechanistic design | Spring 2014 |
| **I-TRACK** | Medium | High | Medium | Efficiently estimate system and component performance using mechanistic design | Fall 2013 (basic)<br>Fall 2014 (advanced) |
| **Finite Element Model** | High | Low | Low | Perform systematic, detailed analyses of system and component behavior | Summer 2014 |

# Track Structure Design Simplified Framework

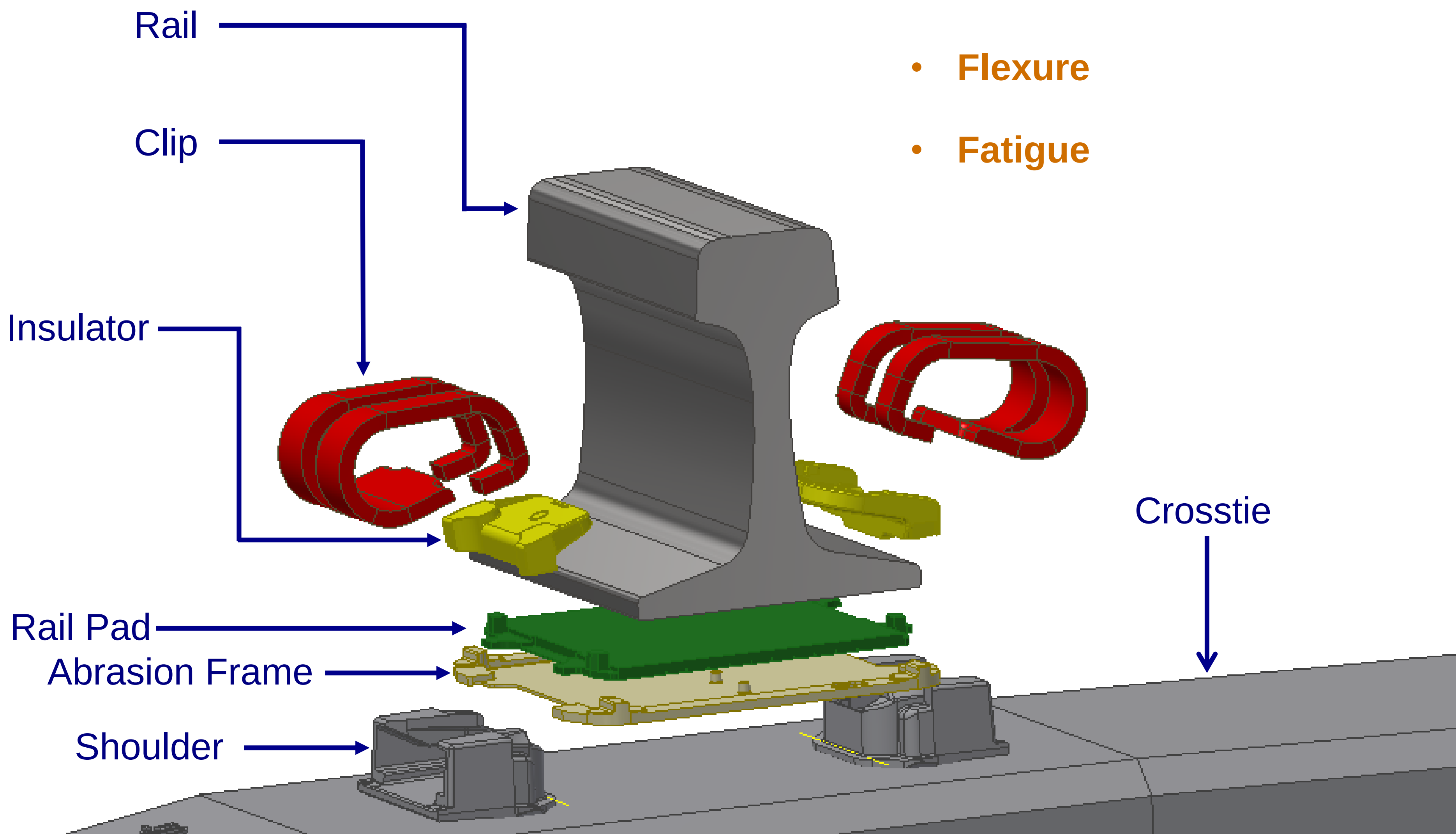


# Design Framework for Typical Track System



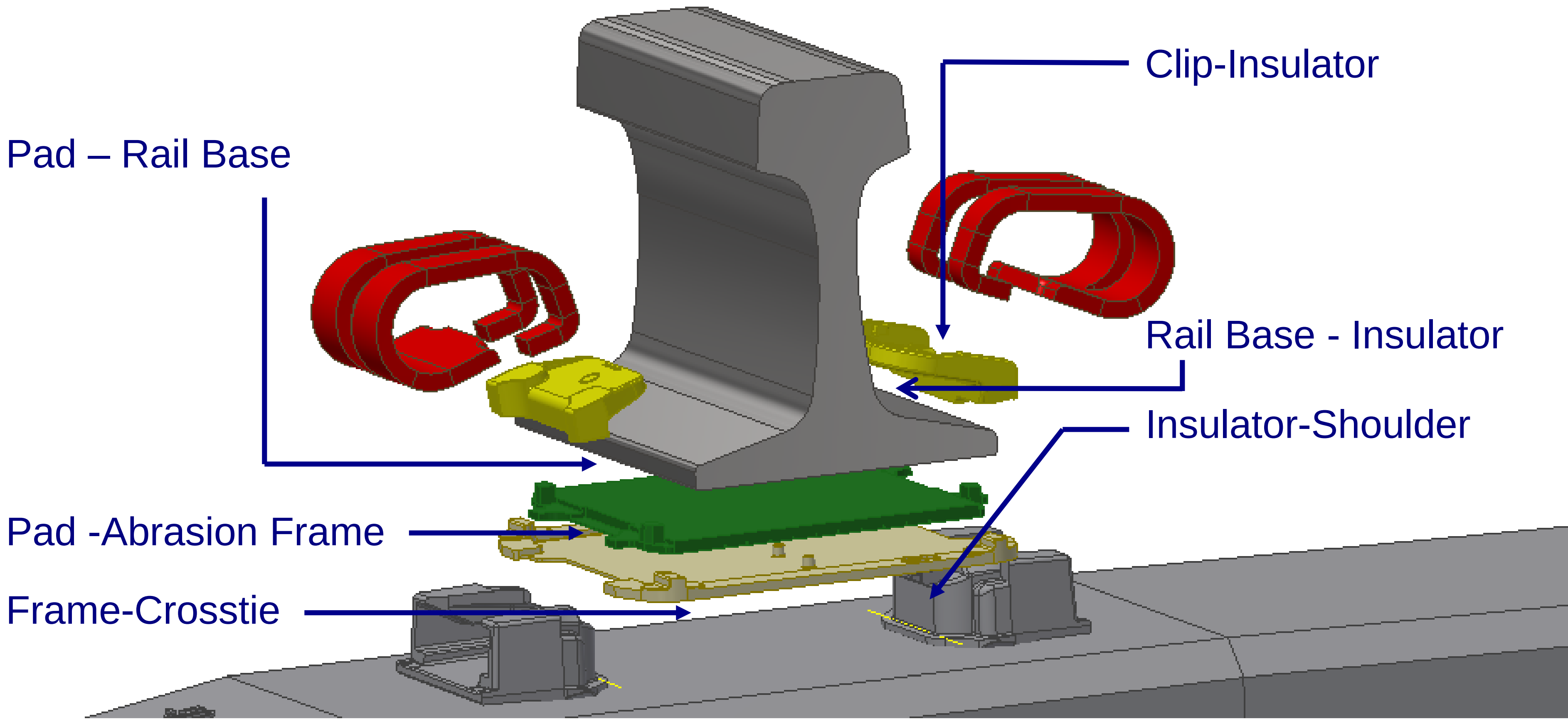
# Component Properties

- Compression
- Shear
- Flexure
- Fatigue

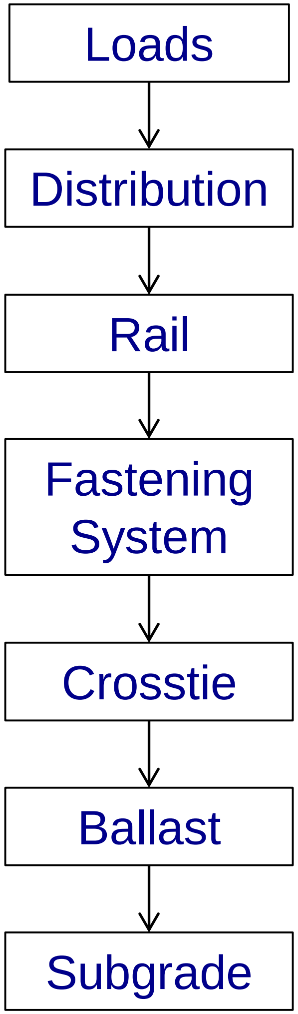


# Interface Properties

- Max Contact Pressure
- Relative Displacement
- Wear Characteristics



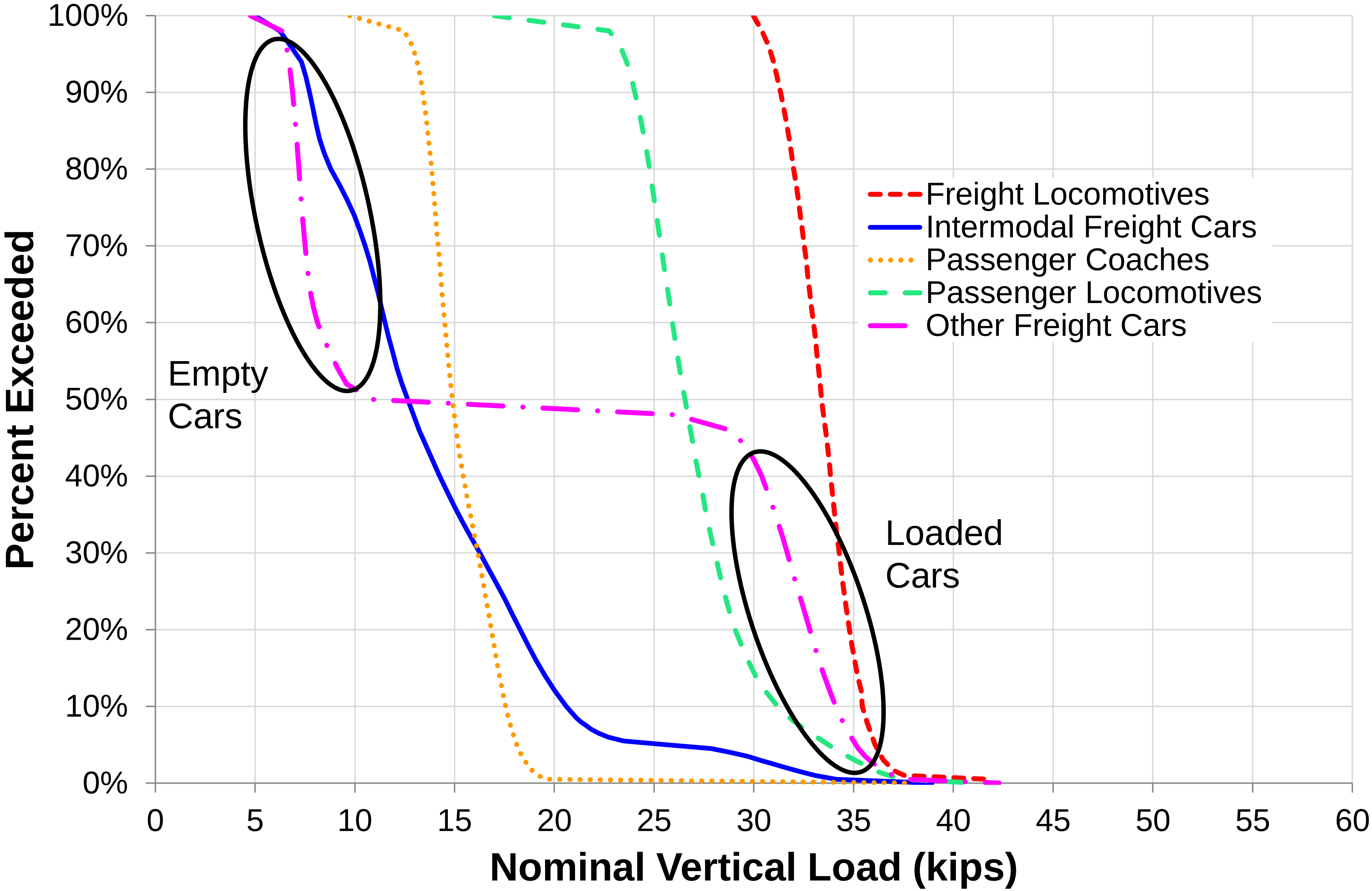
# Mechanistic Design Framework



# Determining System Input Loads

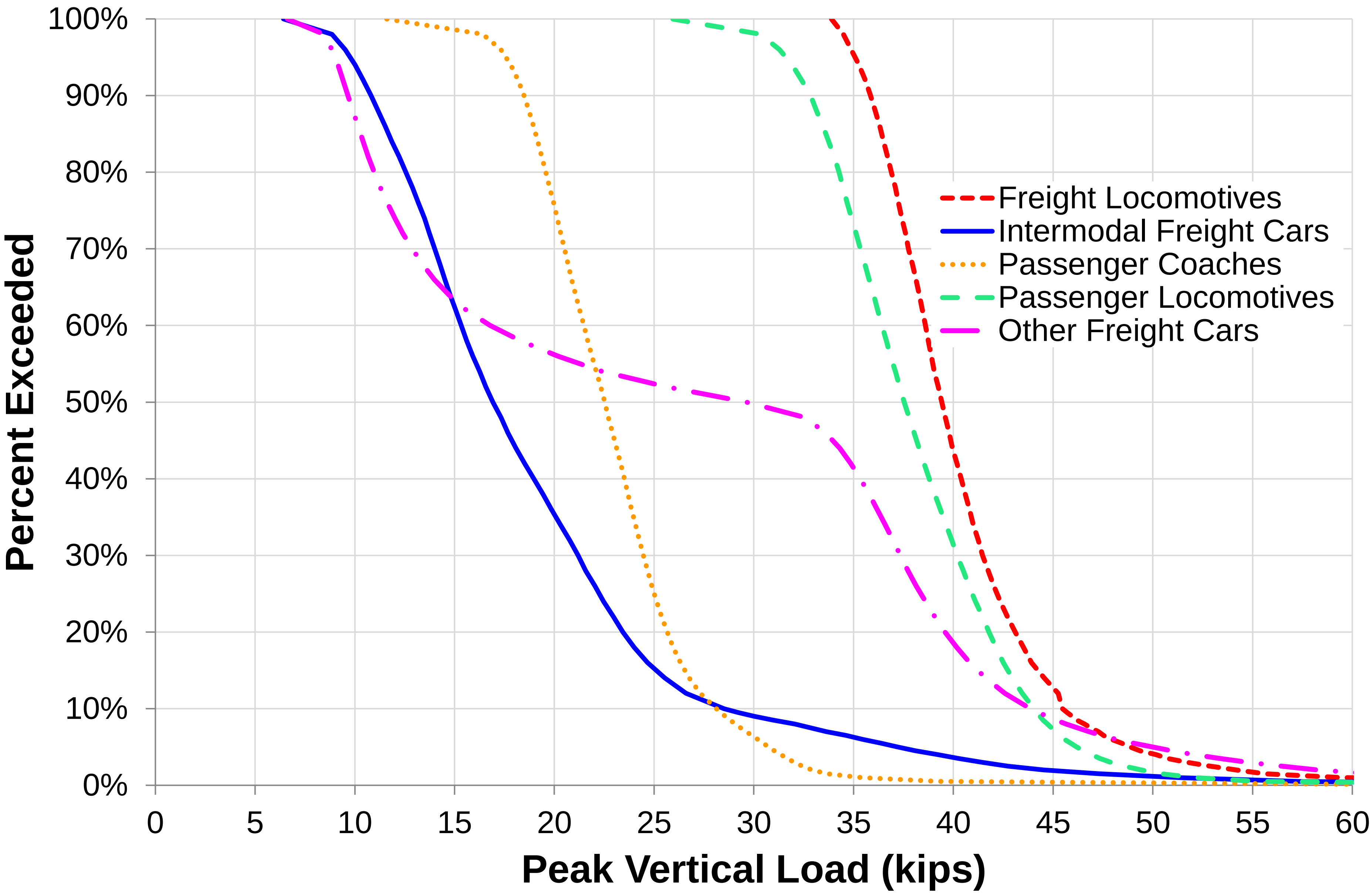
- Quantitative methods of data collection (Step 1):
  - Wheel Impact Load Detectors (WILD)
  - Instrumented Wheel Sets (IWS)
  - Truck Performance Detectors (TPD)
  - UIUC Instrumentation Plan (FRA Tie BAA)
- Most methods above are used to monitor rolling stock performance and assess vehicle health
- Can provide insight into the magnitude and distribution of loads entering track structure
  - Limitations to WILD: tangent track (still need lateral curve data), good substructure (not necessarily representative of the broader rail network)

# Traffic Distribution – Nominal Wheel Loads



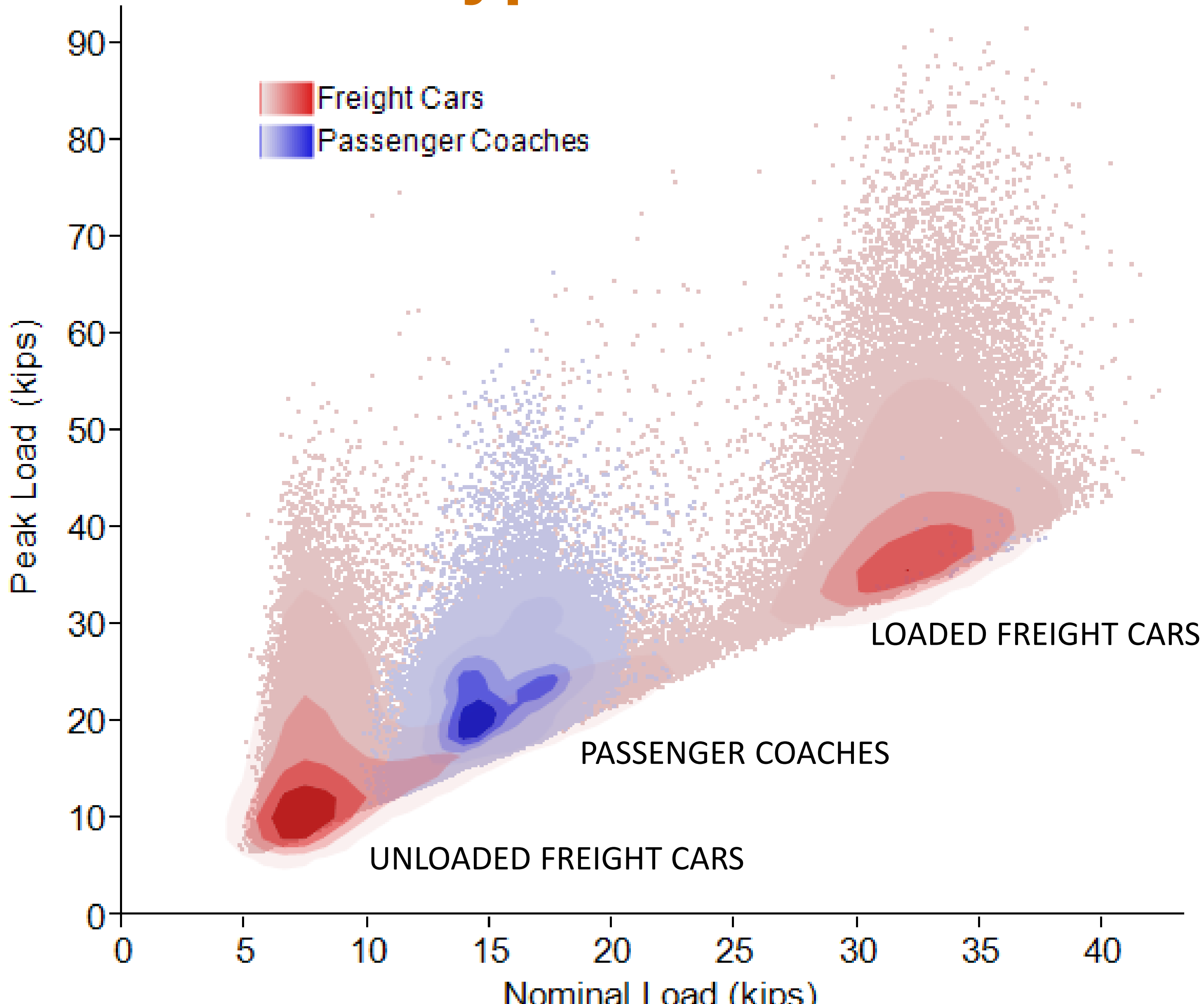

Source: Amtrak – Edgewood, MD (November 2010)

# Traffic Distribution – Peak Wheel Loads



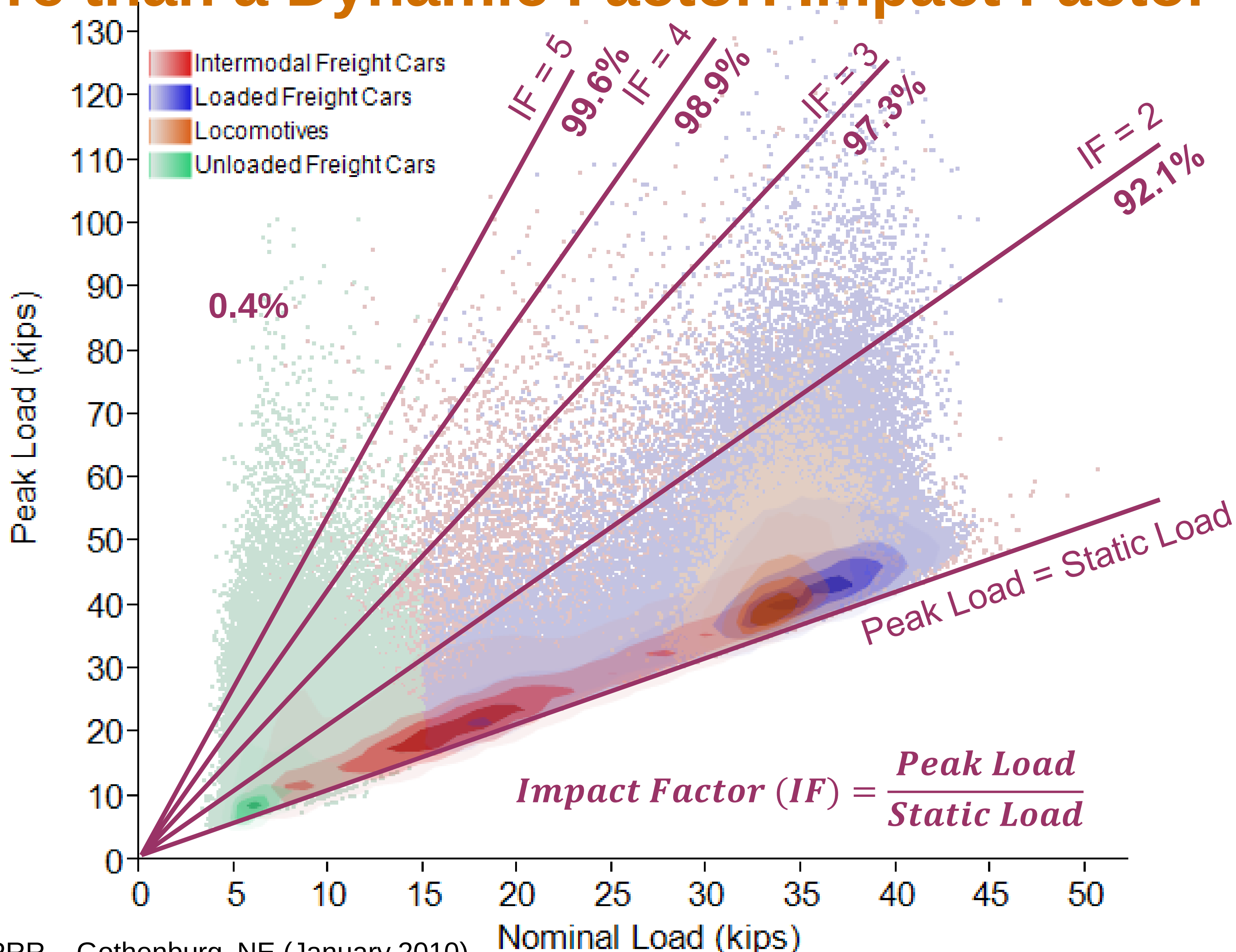

Source: Amtrak – Edgewood, MD (November 2010)

# Effect of Traffic Type on Peak Wheel Load




Source: Amtrak – Edgewood, MD (November 2010)

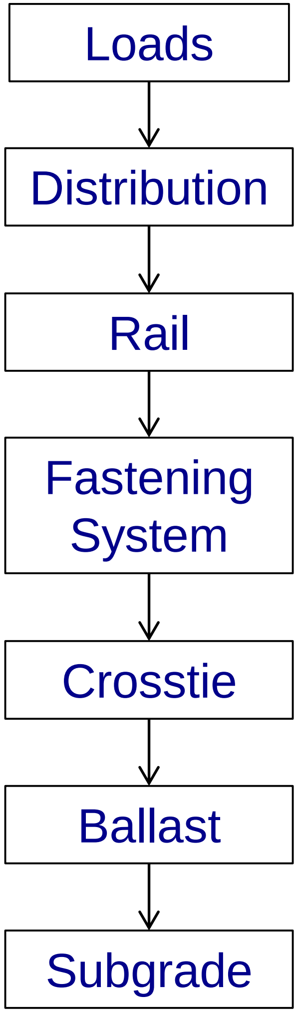
# More than a Dynamic Factor: Impact Factor



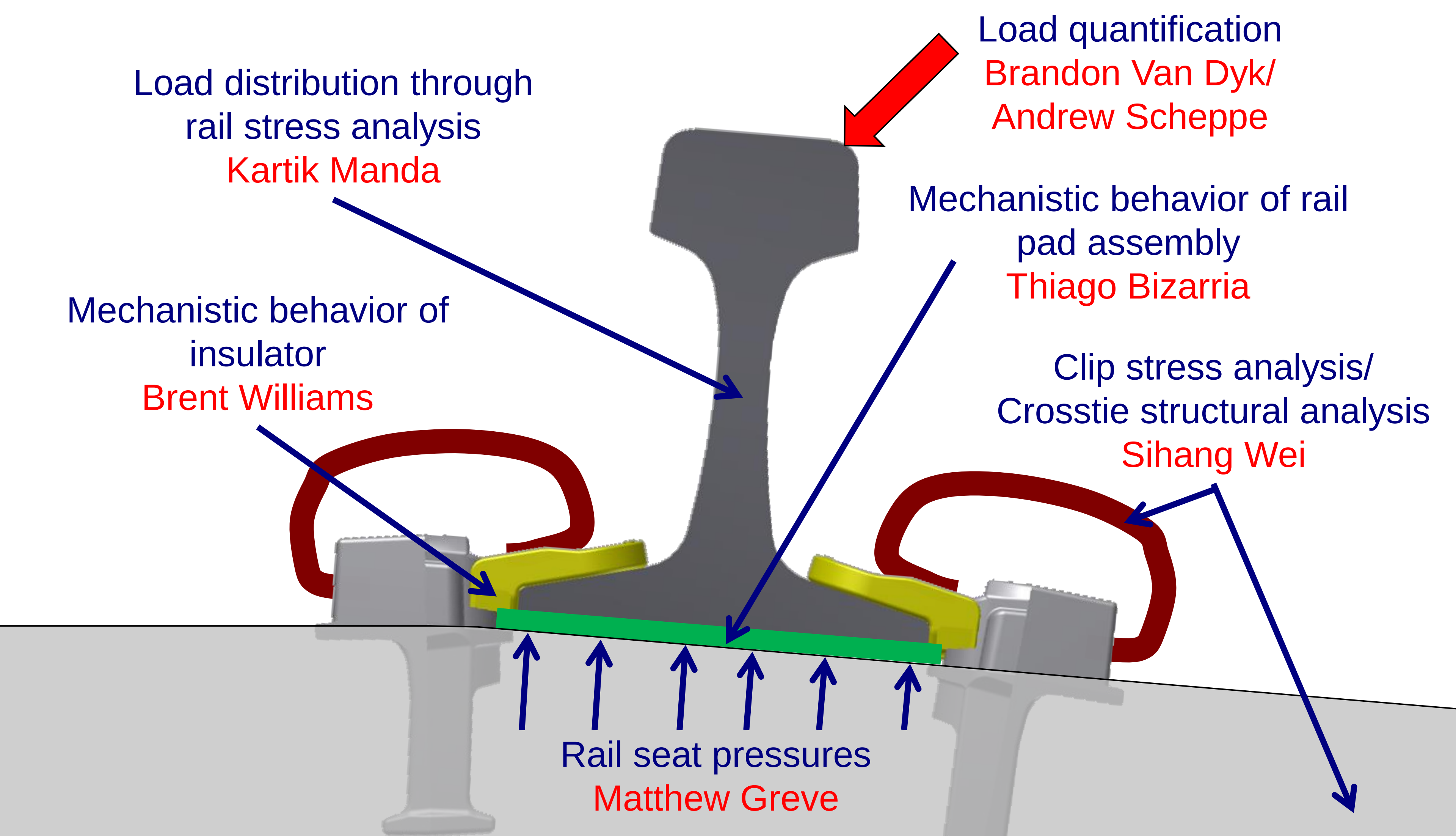

$$\text{Impact Factor }(IF) = \frac{\text{Peak Load}}{\text{Static Load}}$$

Source: UPRR – Gothenburg, NE (January 2010)

# Mechanistic Design Framework



# Current Tie and Fastener Research Coverage




Other research: Concrete materials (Emily Van Dam),
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  - Hanson Professional Services, Inc.
  - CXT Concrete Ties, Inc., LB Foster Company
  - TTX Company

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