# Lateral Load Path Analysis

**FRA Concrete Tie and Fastener BAA – Industry Partners Meeting**

**Incline Village, NV**

**7 October 2013**


Brent Williams, Riley Edwards, Ryan Kernes


U.S. Department of Transportation
Federal Railroad Administration

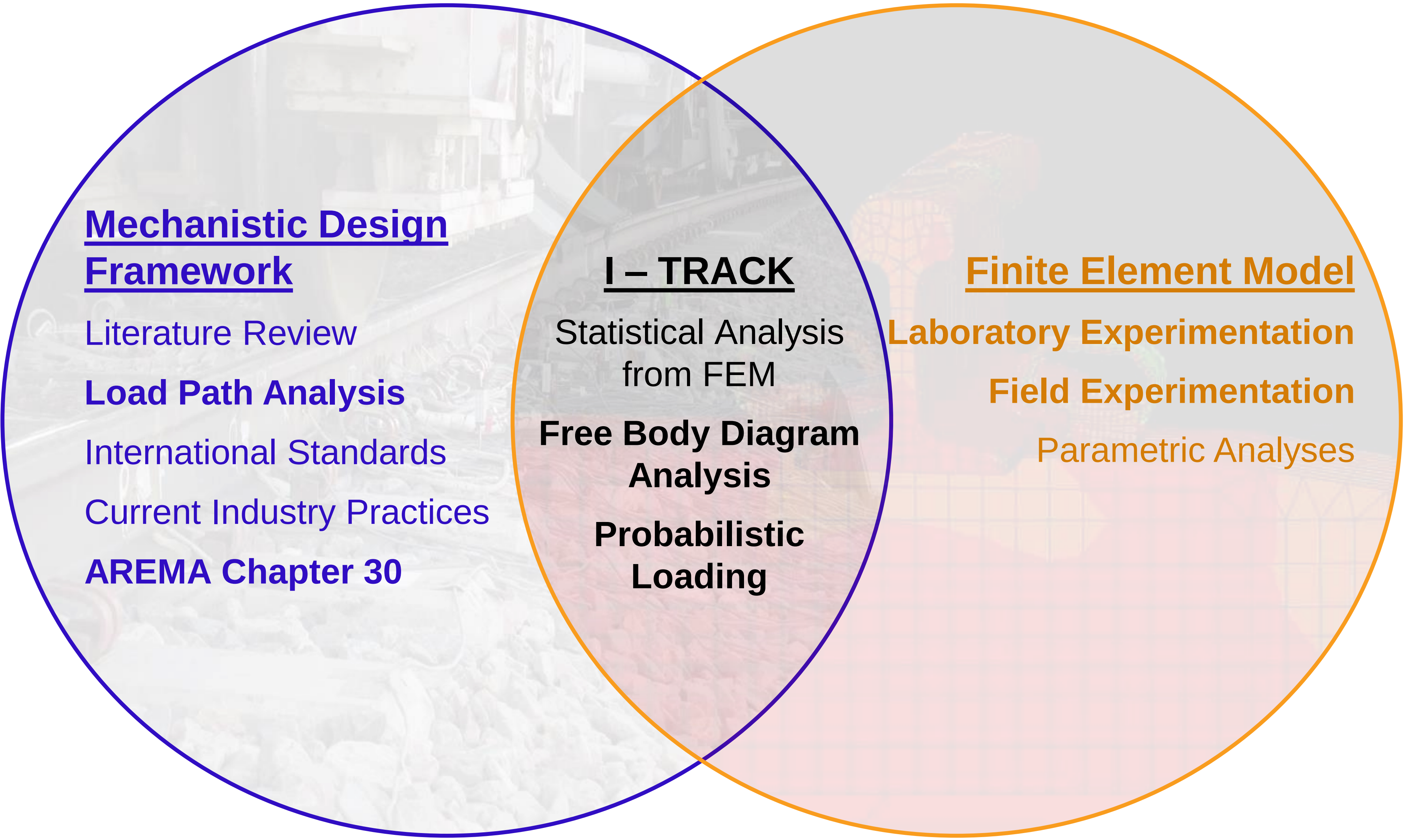
RAILTEC
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

ASSOCIATION OF AMERICAN RAILROADS

# Outline

- Background
- Purpose of lateral force measurement
- Defining the lateral load path
- Lateral force measurement technology
- Preliminary results and conclusions
- Future work

# Overall Project Deliverables



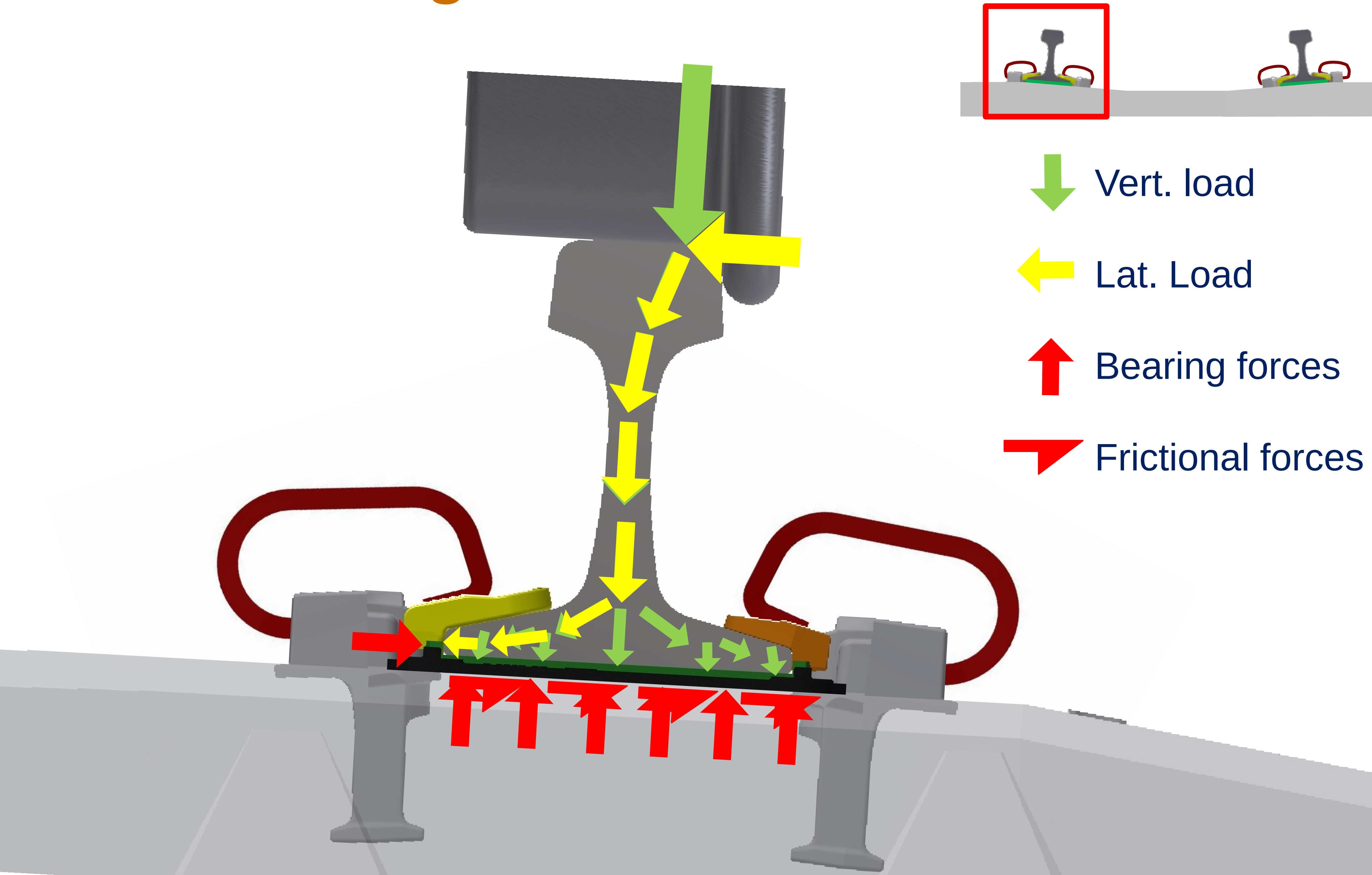
# Background

- 25 million concrete crossties are in use on North American heavy haul freight railroads
- **Industry trends**:
  - Many variations in fastening system design and performance
  - Fastening system components are failing earlier than their design life
  - Increasing heavy axle loads (HAL) and traffic volumes
  - Shared infrastructure with both HAL and high speed rail (HSR)
- **Industry need**:
  - Fastening systems that economically withstand increasingly demanding loading conditions
    - Minimizing maintenance procedures allows for increased operating efficiency and capacity

# Purpose of Lateral Force Measurement

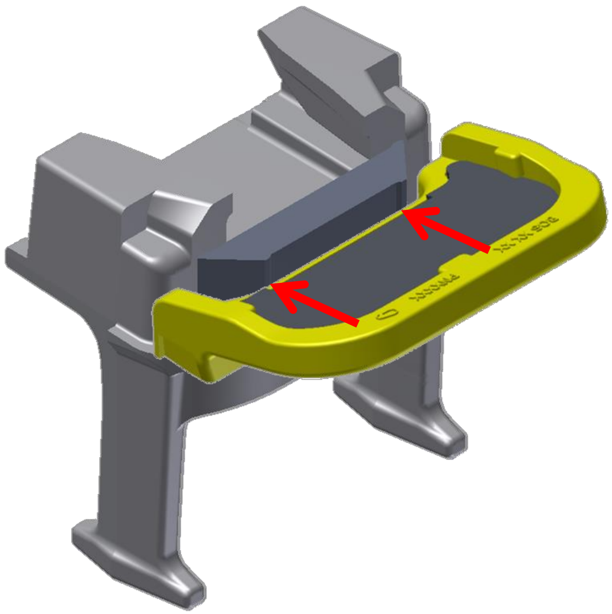
- **Quantify lateral loading conditions to aid in the mechanistic design of fastening systems**
- Understand demands on fastening system components under loading conditions known to generate failures
- Gain understanding of the lateral load path by:
  - Quantifying forces and stresses acting on the insulator and shoulder
  - Quantifying the distribution of lateral forces in fastening system
    - e.g. Bearing on shoulder, frictional resistance from rail pad assembly or clip, etc.
  - Understanding the causes of variation on lateral load distribution among adjacent crossties

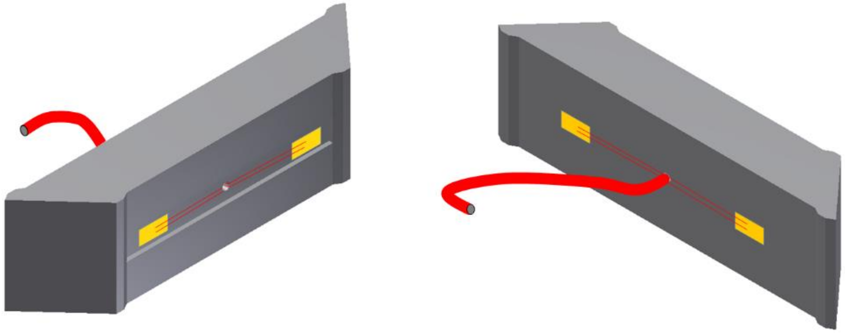
# Defining the Lateral Load Path



# Lateral Force Measurement Methodology

- Lateral Load Evaluation Device (LLED)
  - Original shoulder face is removed
  - Insert designed as a beam and optimized to replace removed section and maintains original geometry
  - Measures bending strain of beam under 4-point bending
    - Measuring bending strain is a proven technique



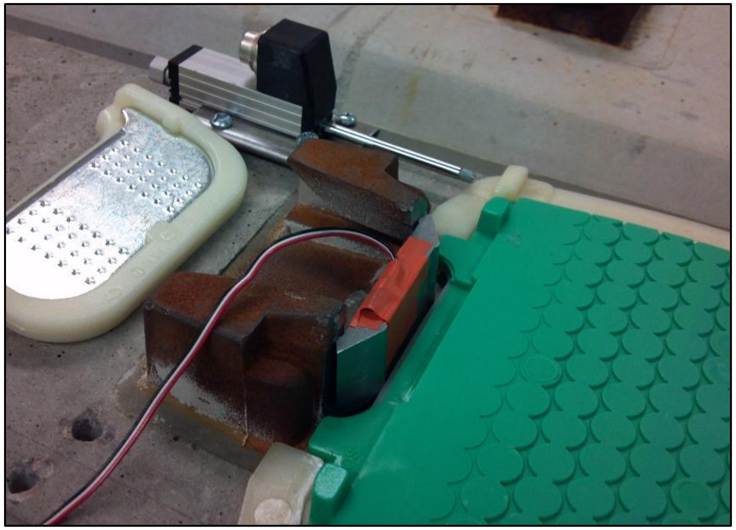


# Laboratory Proof of Concept

- Instrumented shoulder face insert tested on Pulsating Load Testing Machine (PLTM) at UIUC
- Lateral load: 1,800 lbf (8 kN) to 18,000 lbf (80 kN)
- Varied L/V ratio from 0.1 to 0.5
- Dynamic loading at 3 Hz
- Representative loading conditions
  - Sharp curvature
  - Demanding conditions

# Preliminary Laboratory Conclusions

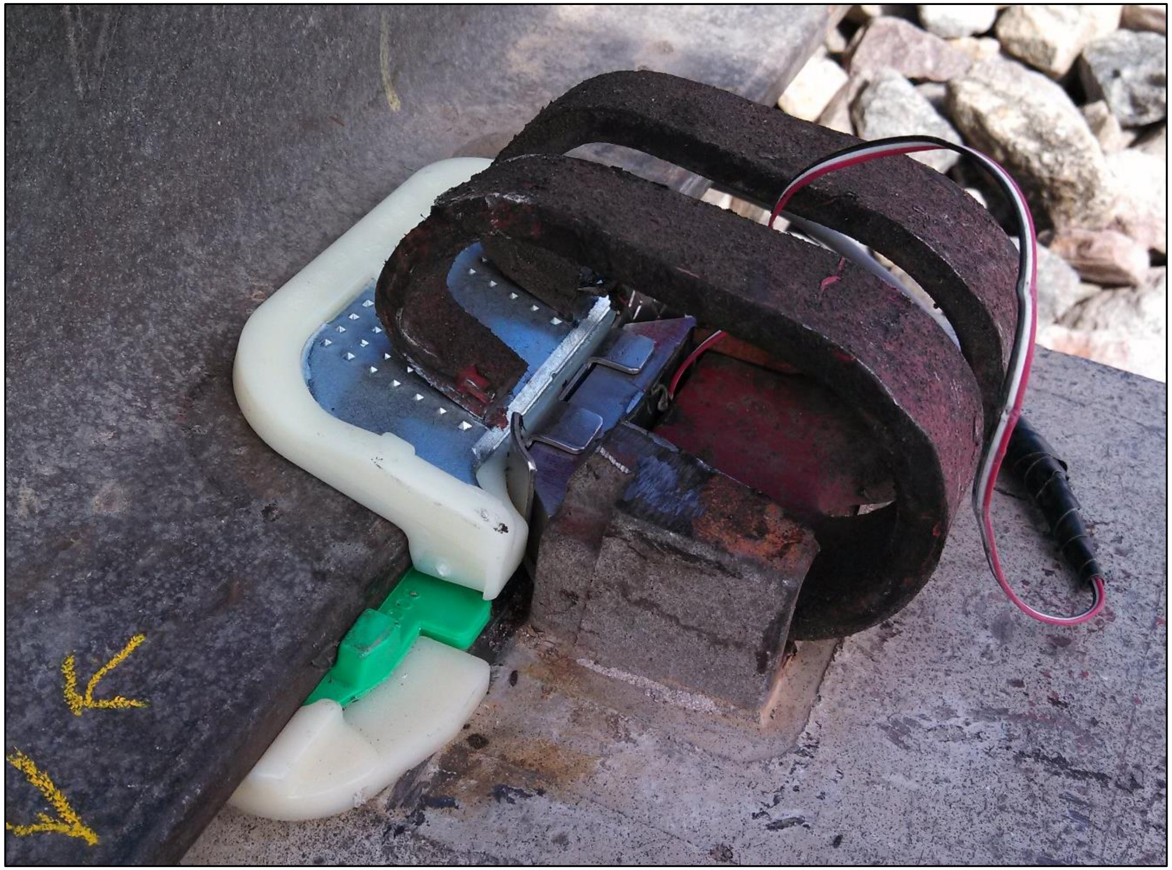
- Percentage of lateral load transferred into shoulder depends on stiffness at insulator-shoulder interface
- Lower coefficients of friction between concrete crosstie and rail pad result in increased lateral load through post
- Successful laboratory testing results make LLED a viable way to measure lateral load in the field



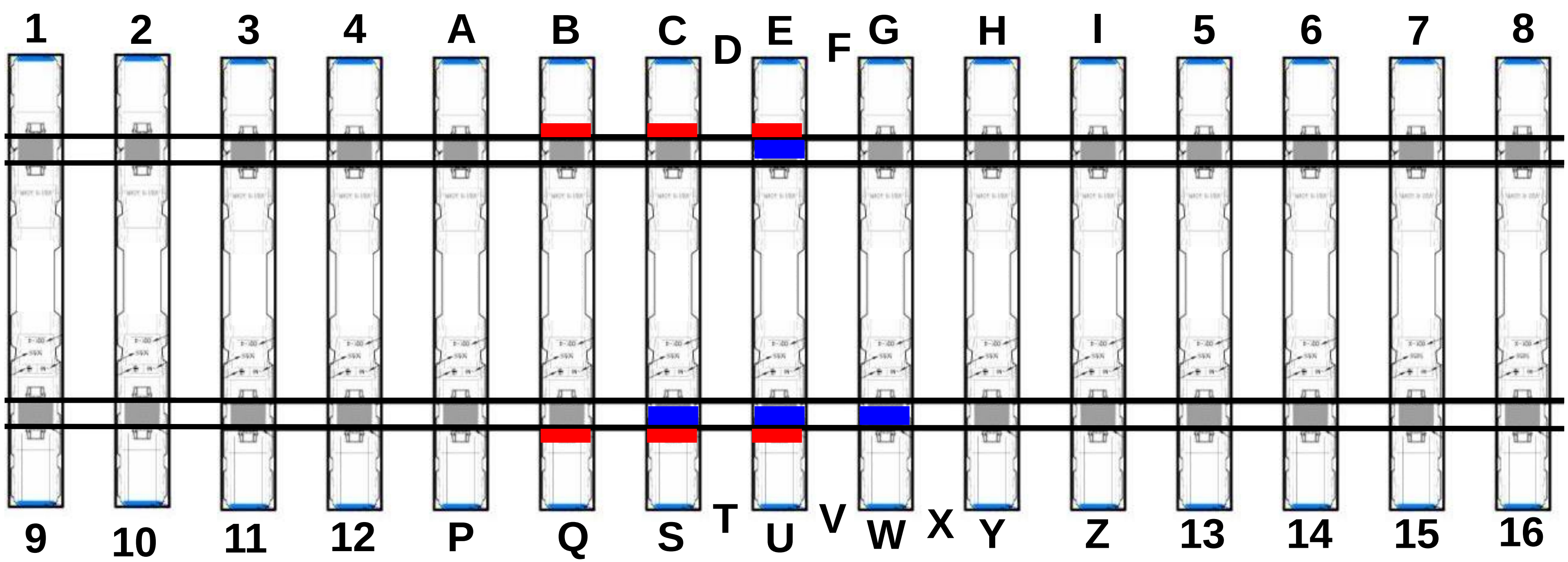
*Laboratory Installation*

*Field Installation*

# Field Experimentation



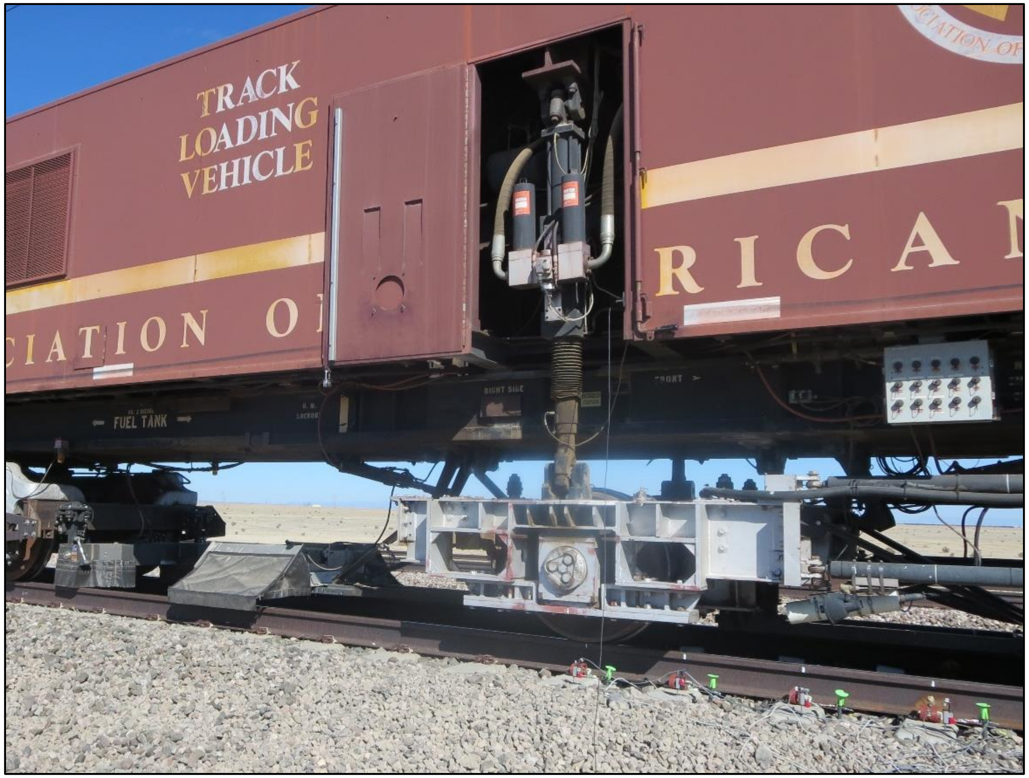
# Map of Instrumentation Technologies



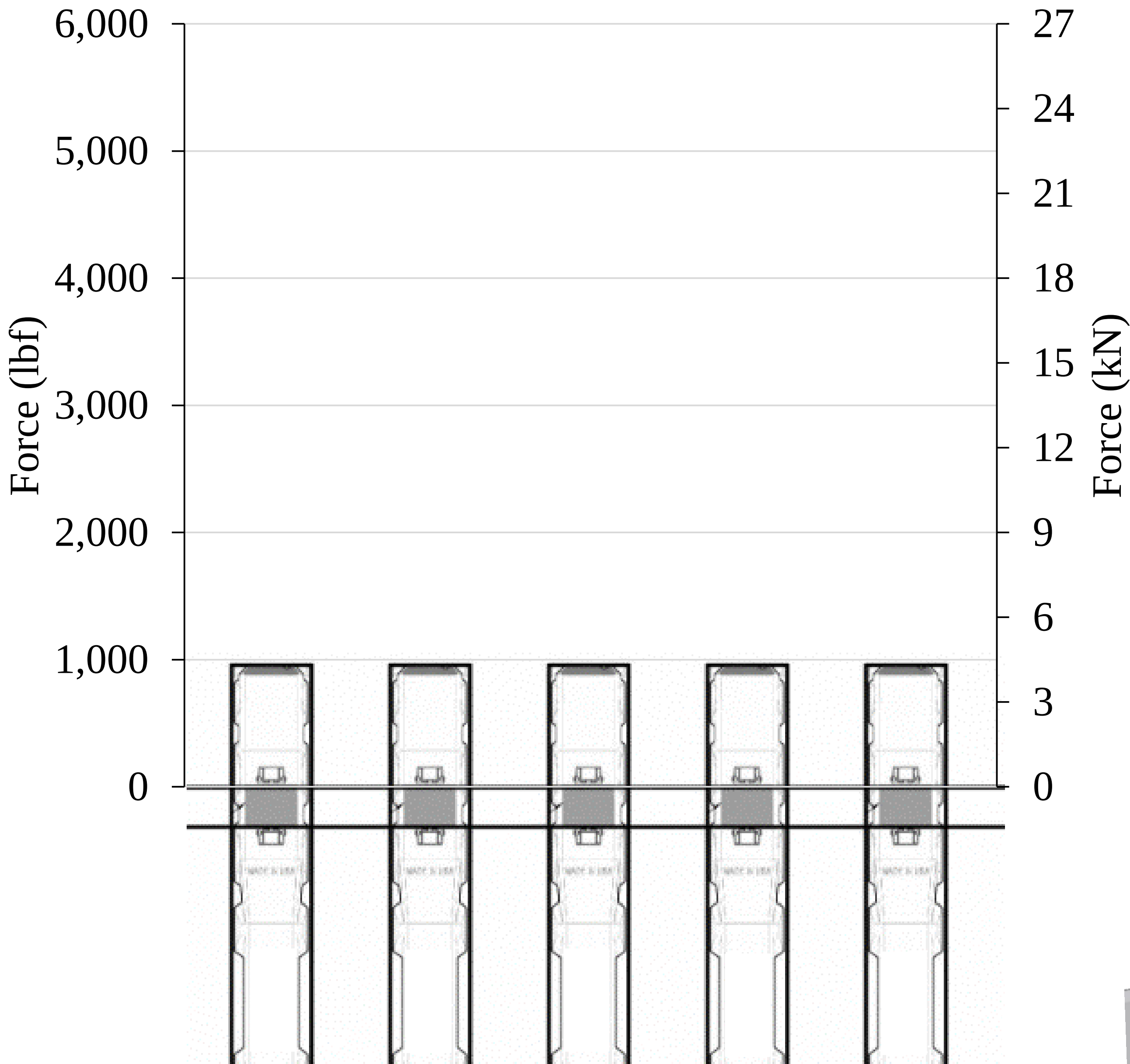

Rail seat with all measurement technologies

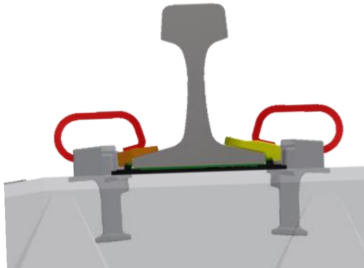
Lateral Load Evaluation Device (LLED)

# Tangent Track
# Track Loading Vehicle (TLV)
# V = 40 kip (177.9 kN)
# L = Variable

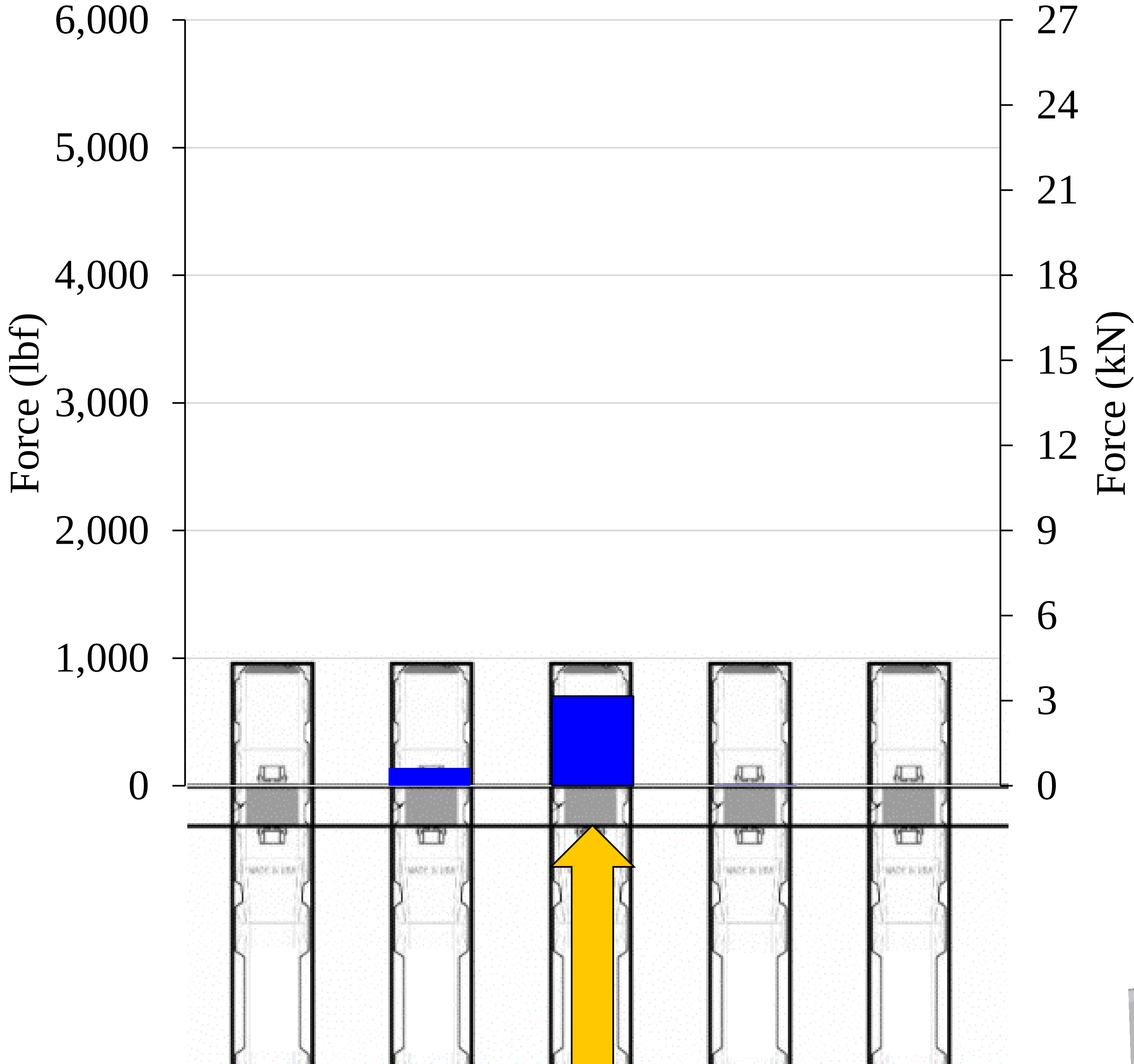


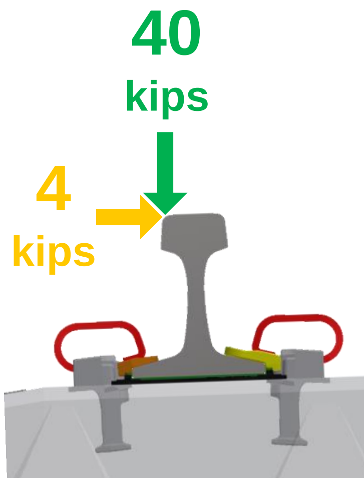
# Lateral Load Transfer



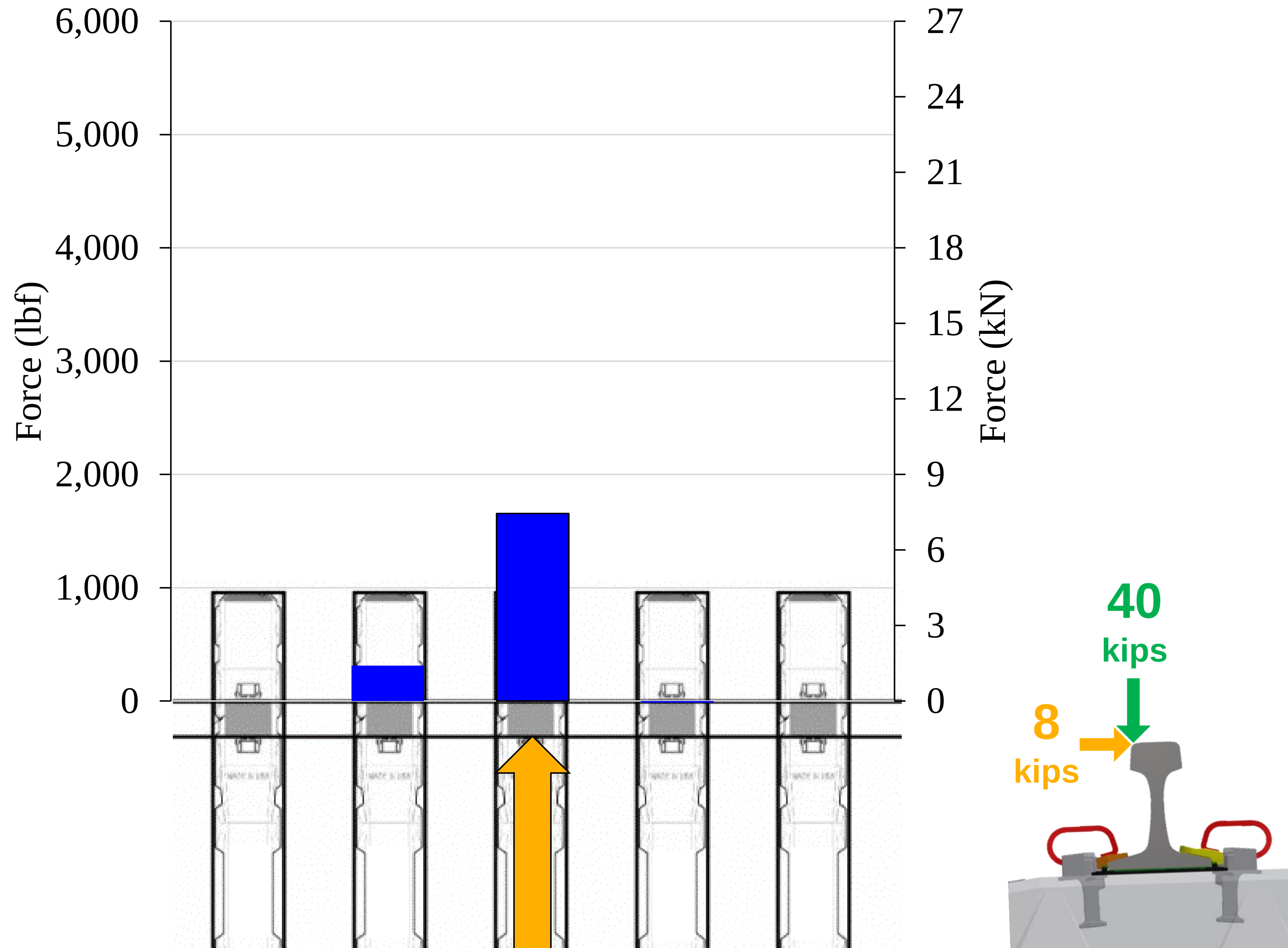



# Lateral Load Transfer

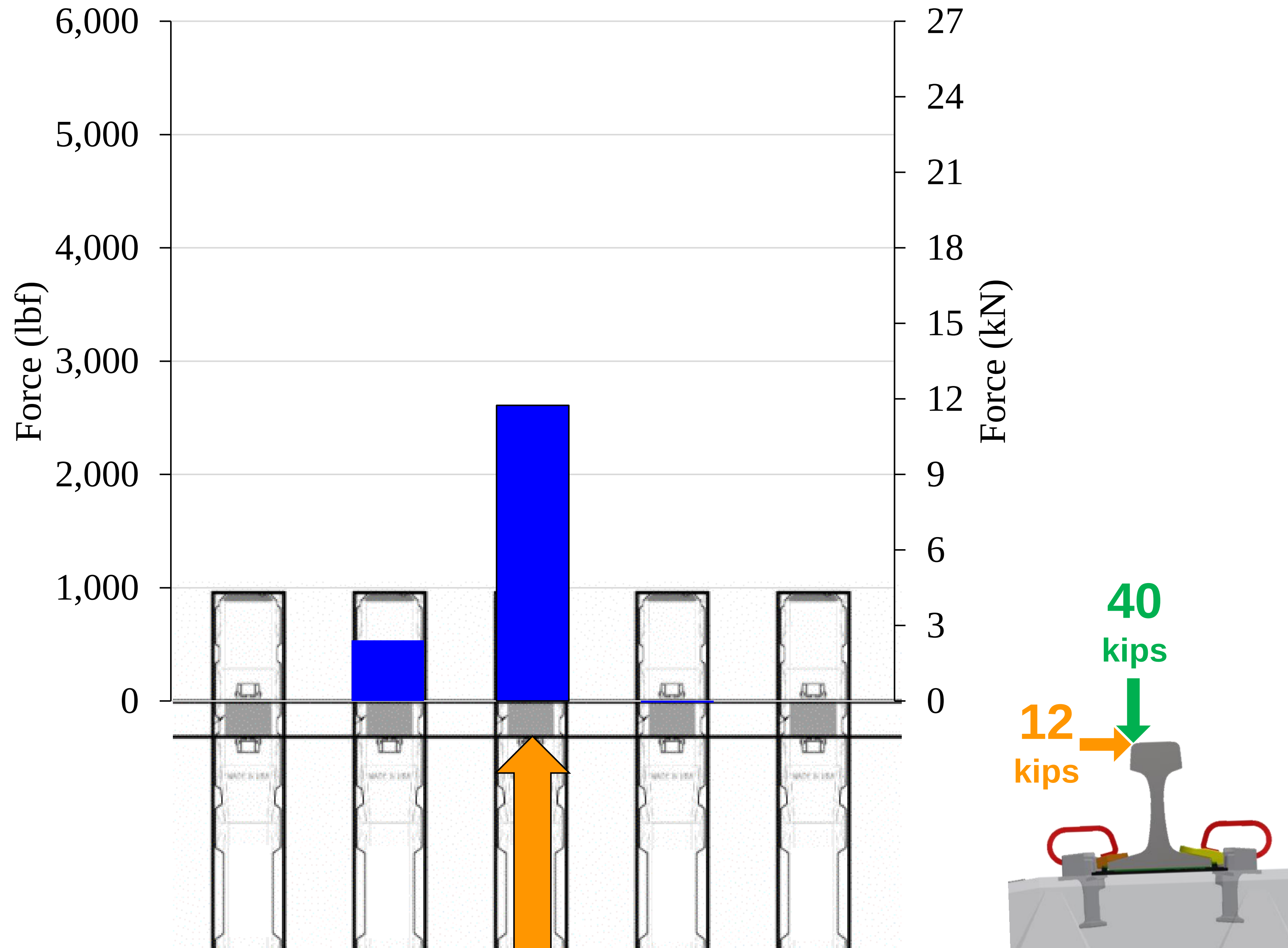


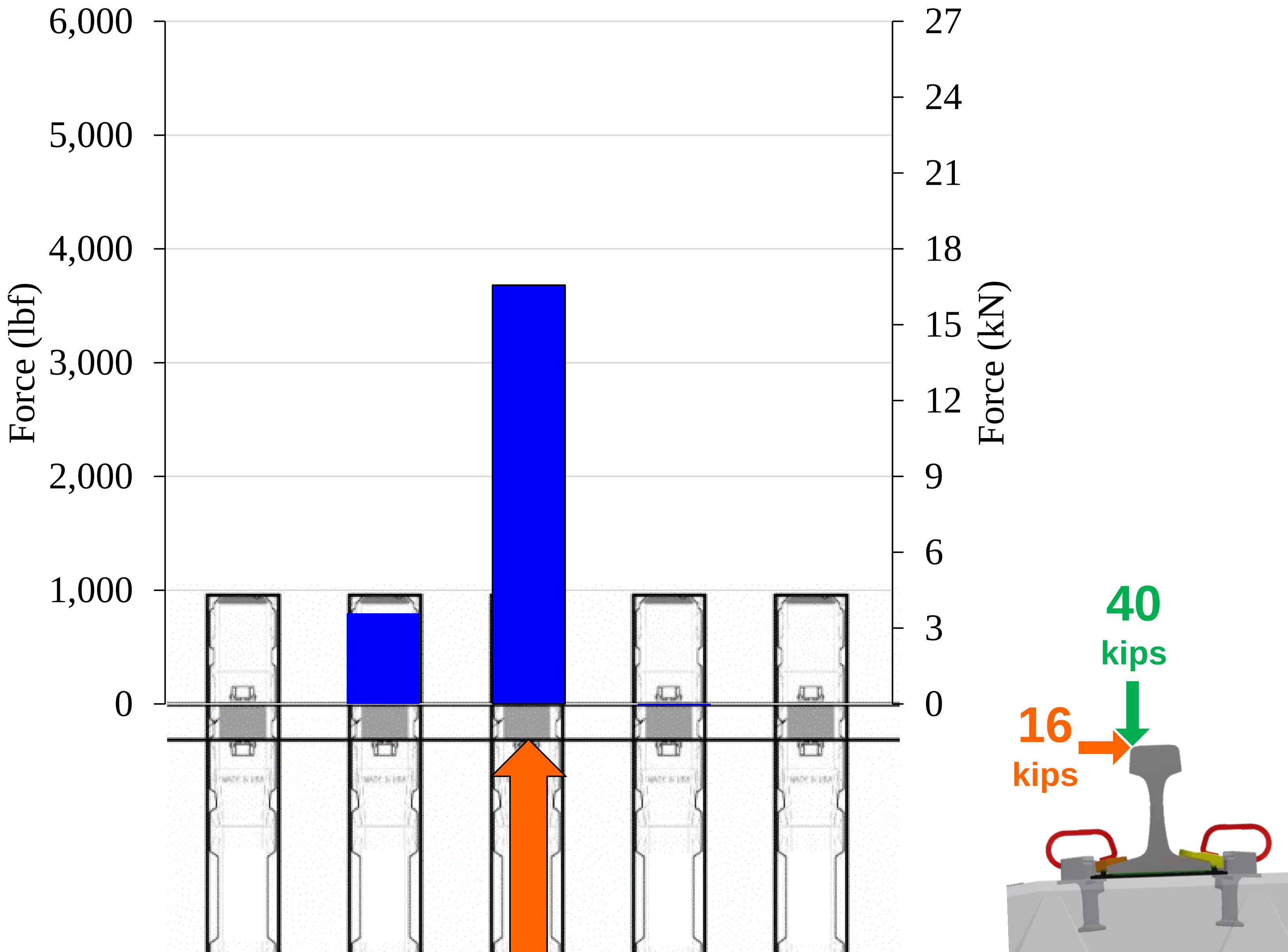
# Lateral Load Transfer



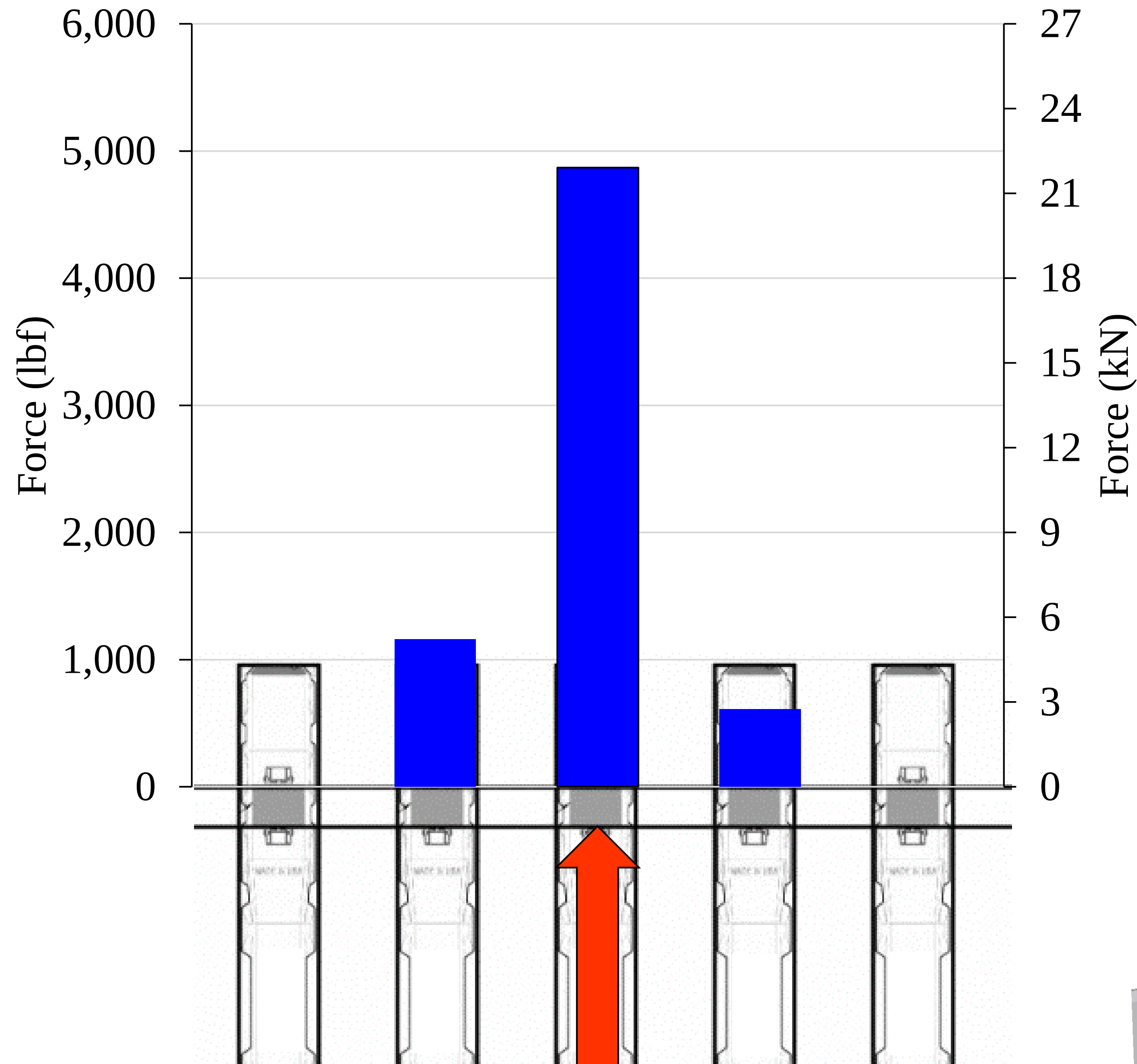
# Lateral Load Transfer

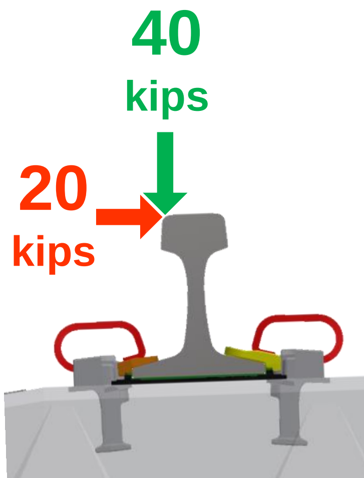


# Lateral Load Transfer

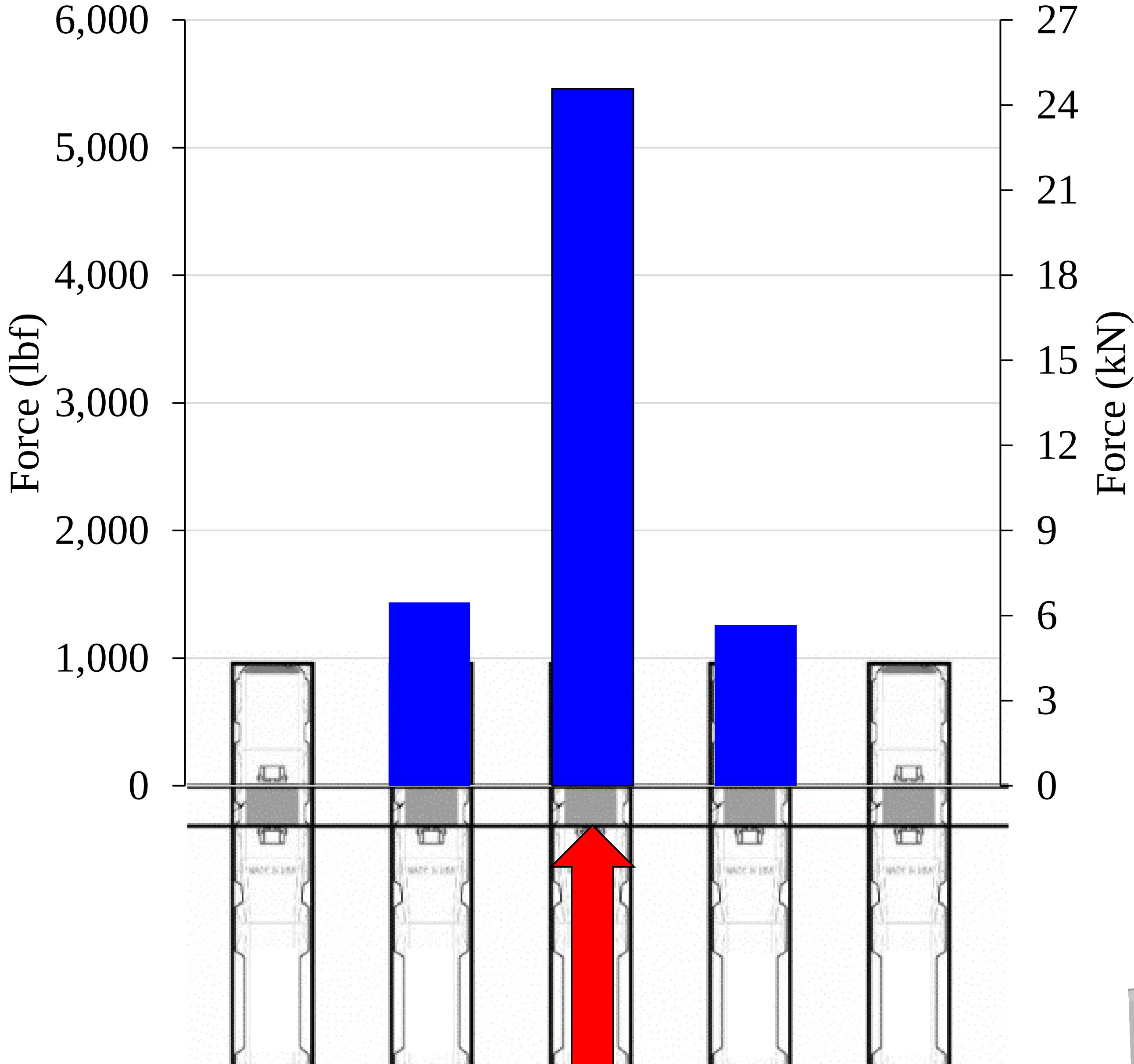


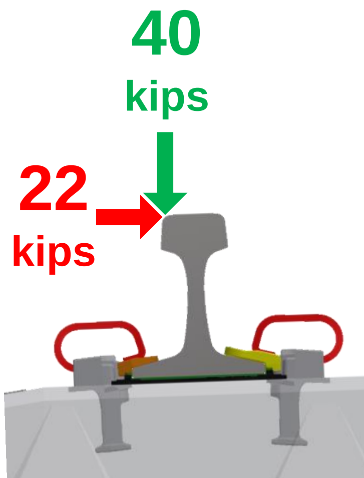
# Lateral Load Transfer



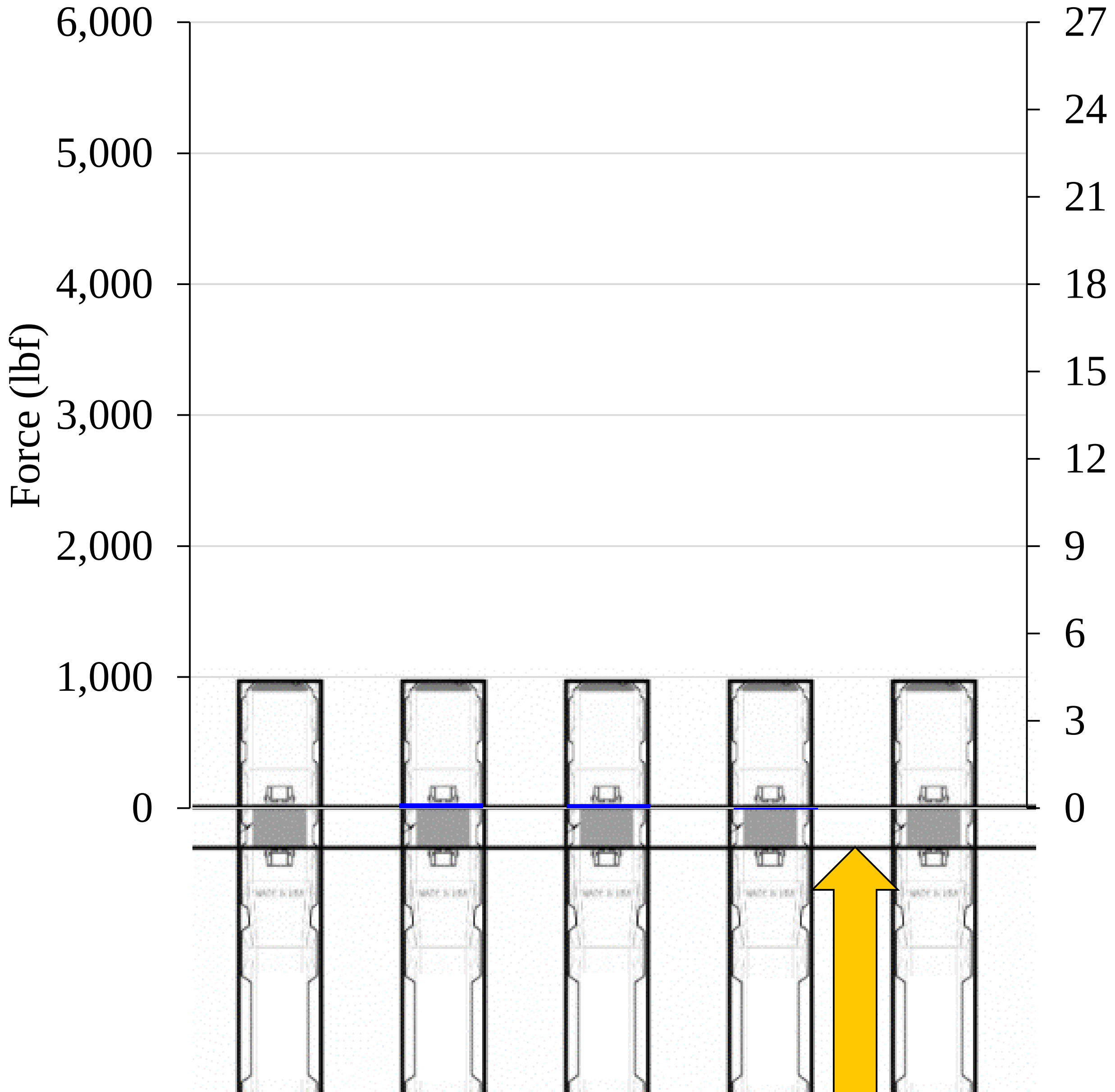



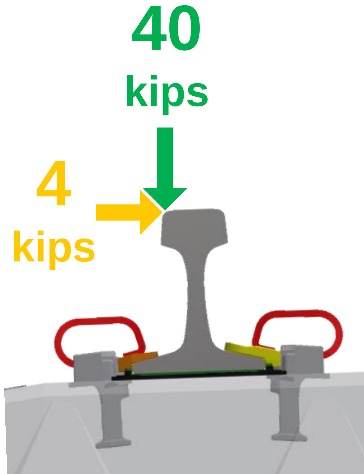
# Lateral Load Transfer



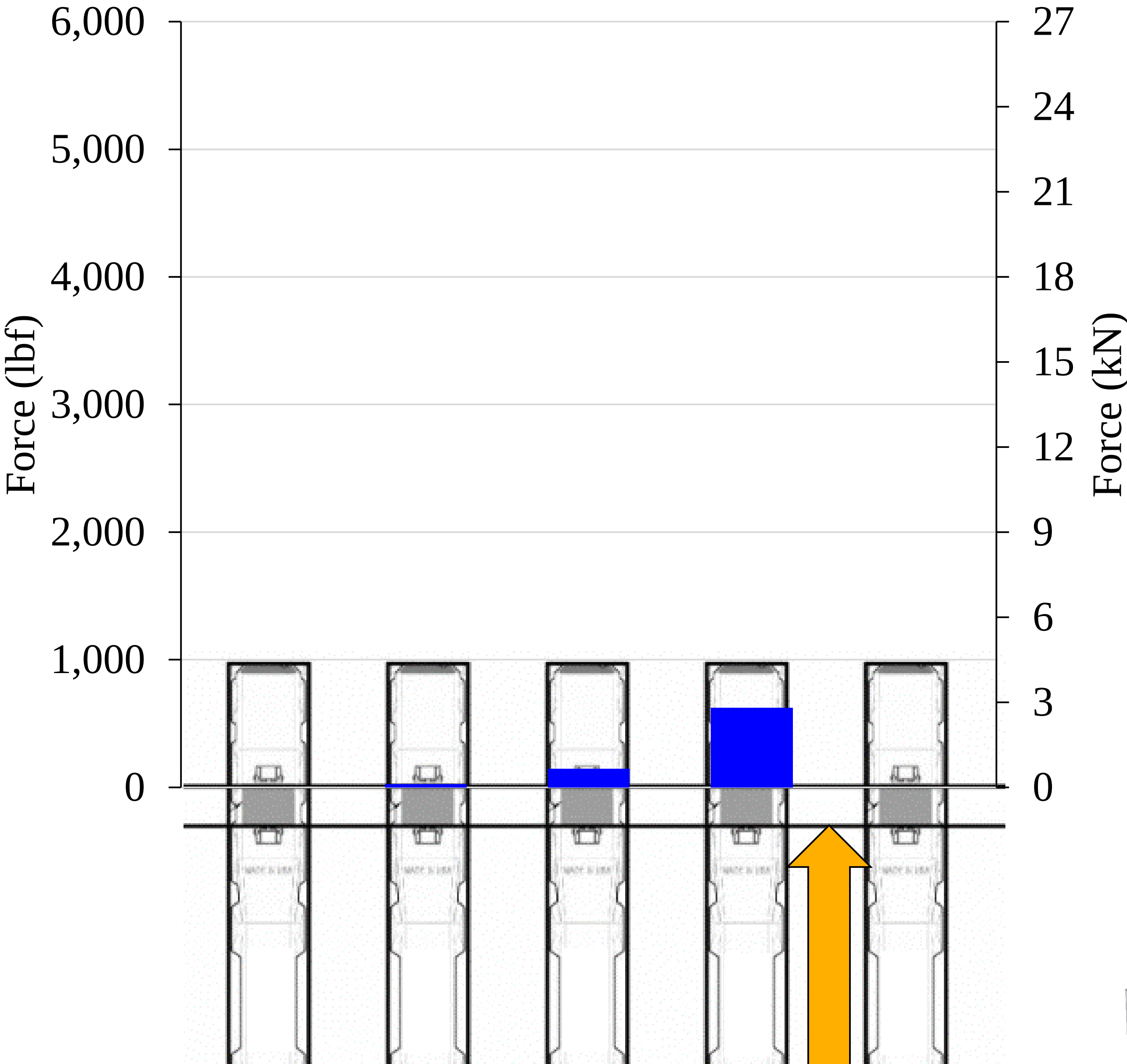



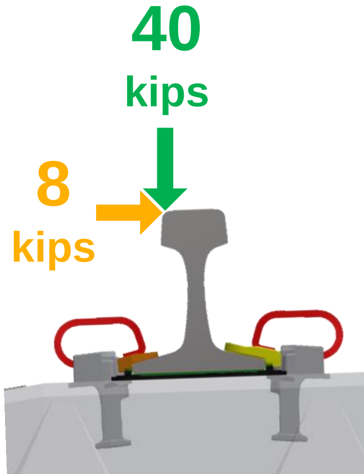
# Lateral Load Transfer



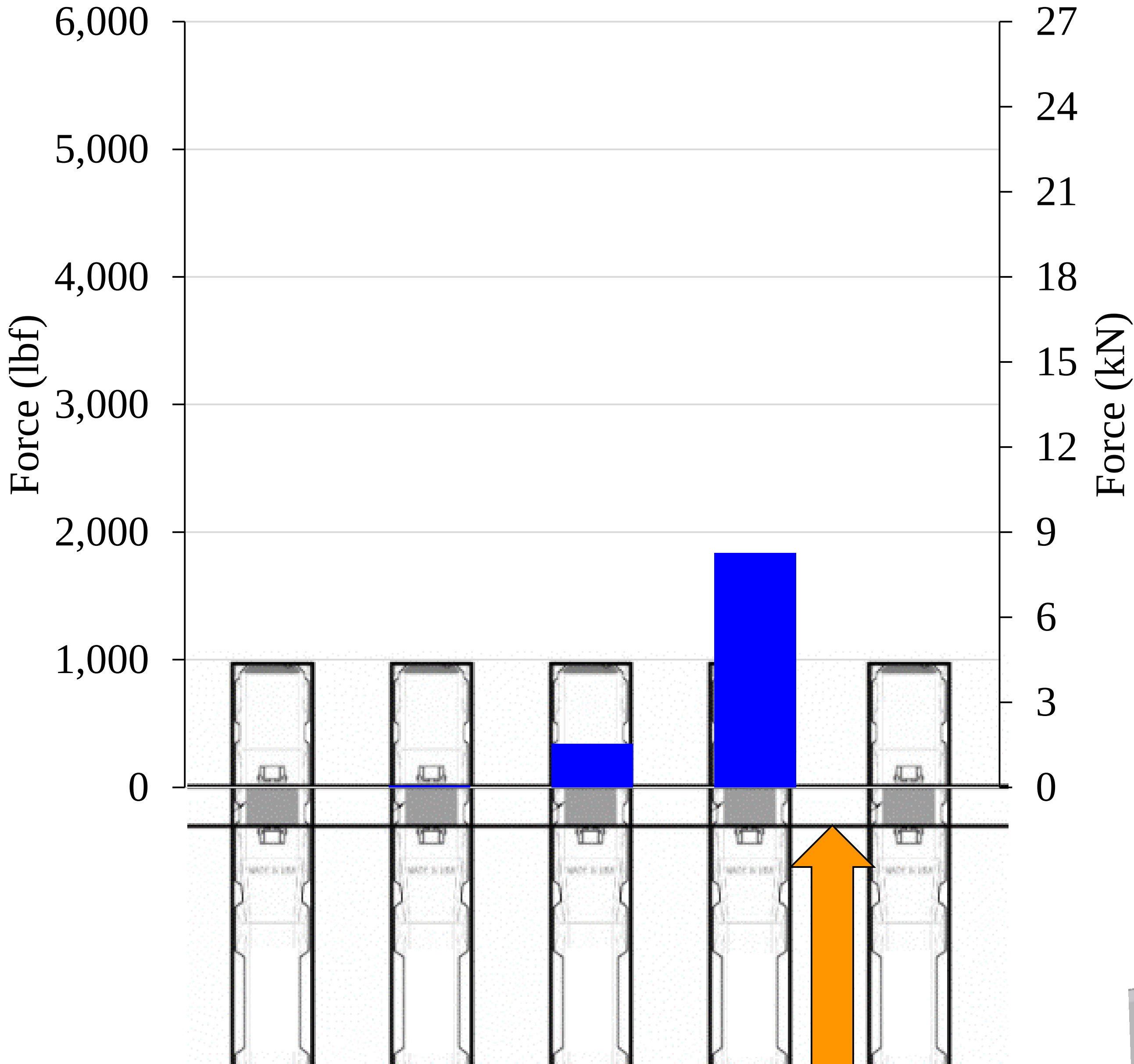



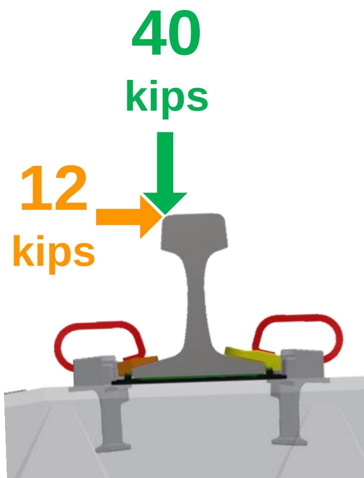
# Lateral Load Transfer



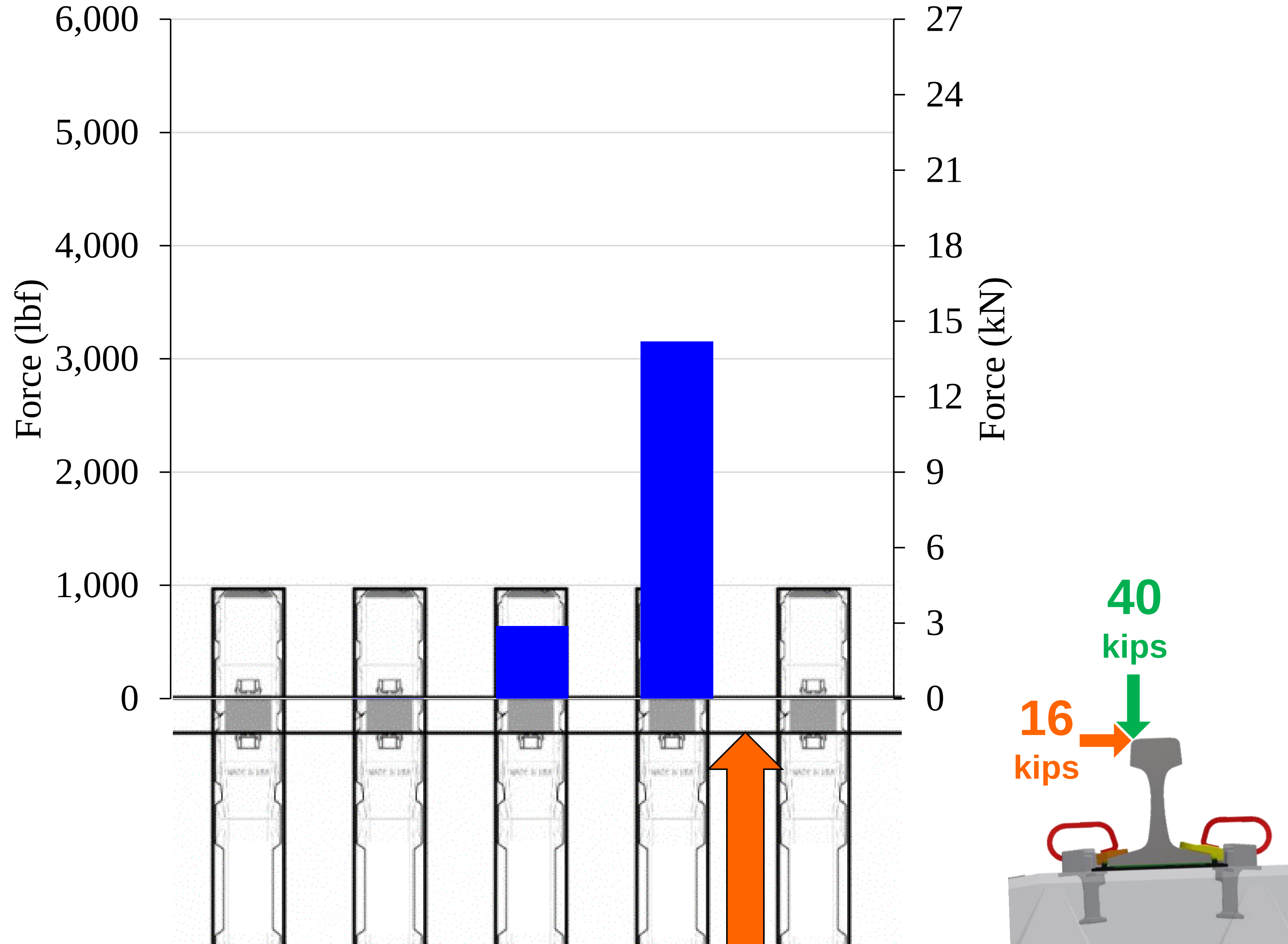



# Lateral Load Transfer

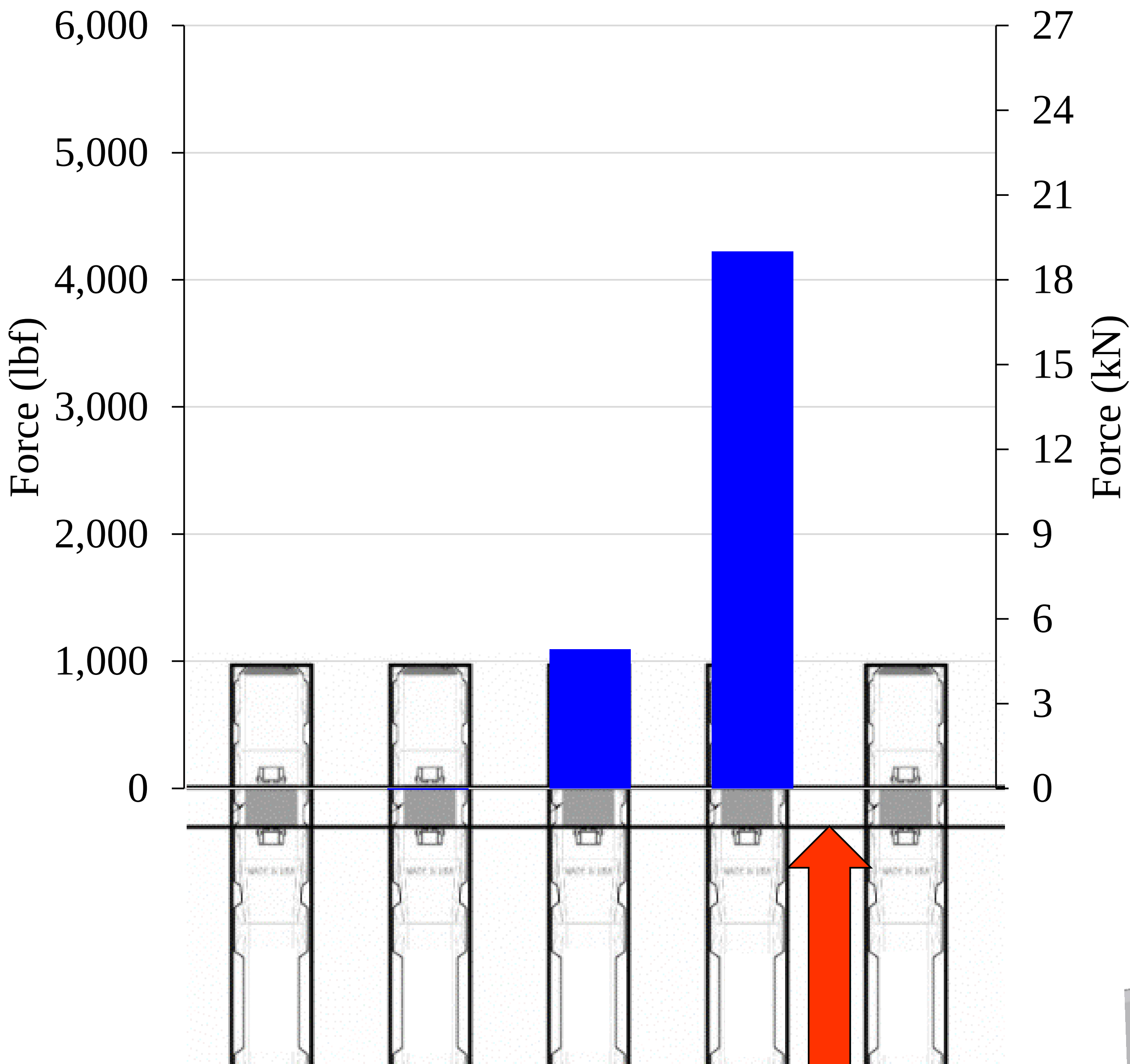


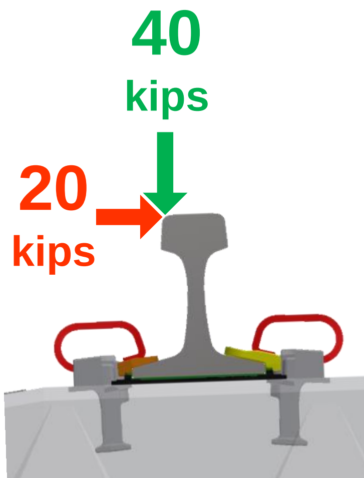



# Lateral Load Transfer

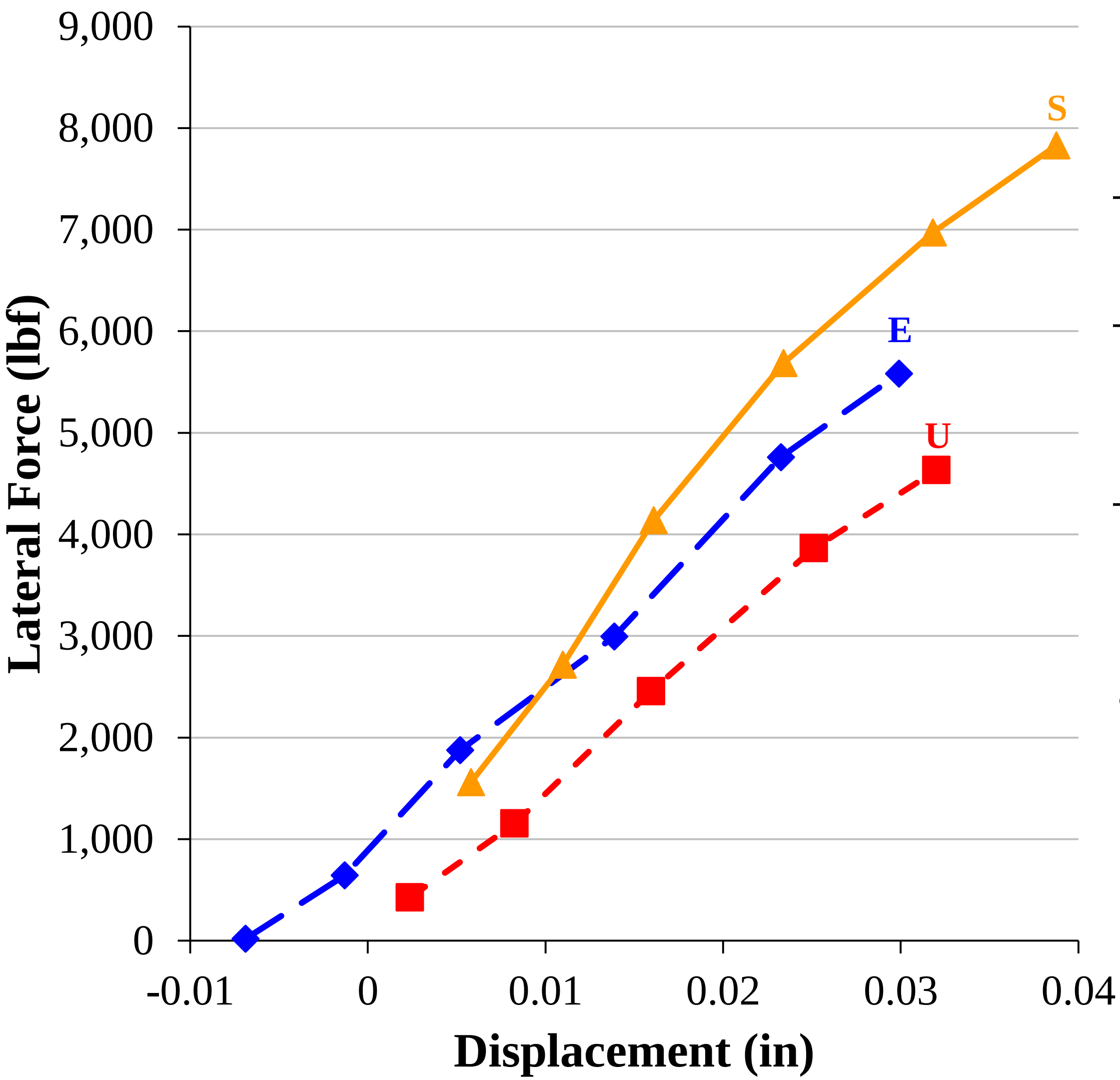


# Lateral Load Transfer



# Effects of Lateral Fastening System Stiffness




| Rail Seat | Lateral Stiffness (lbf/in) | Max. Force (lbf) |
|---|---|---|
| S | 192,498 | 7,828 |
| E | 155,369 | 5,582 |
| U | 146,322 | 4,632 |

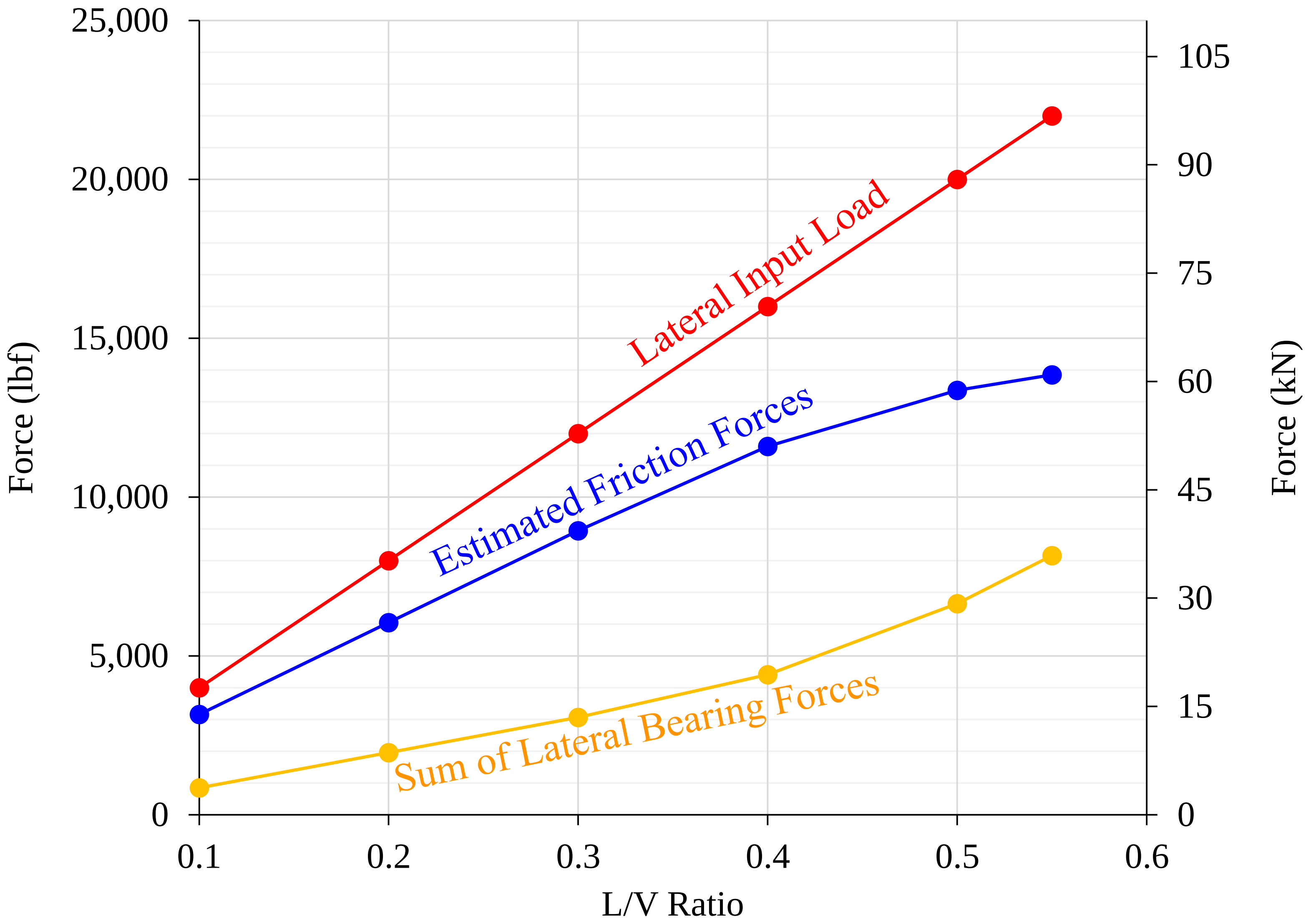
- A higher lateral stiffness leads to more load being carried by that particular rail seat

# Lateral Load Restraint

## Distribution within Fastening System

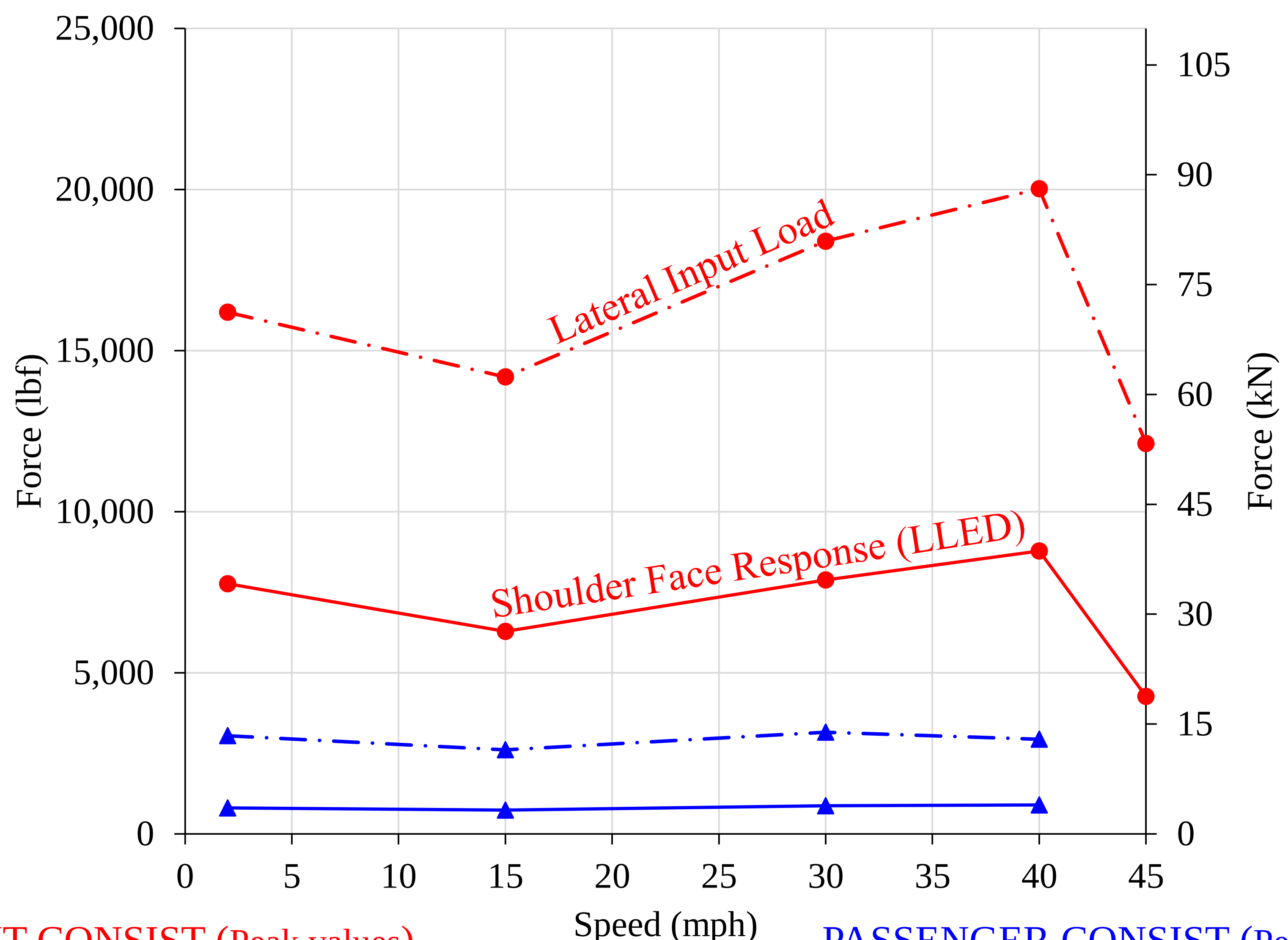
# Lateral Load Restraint

## Tangent Track, TLV



# Lateral Load Restraint

## Curved Track (High Rail), Passenger and Freight Runs

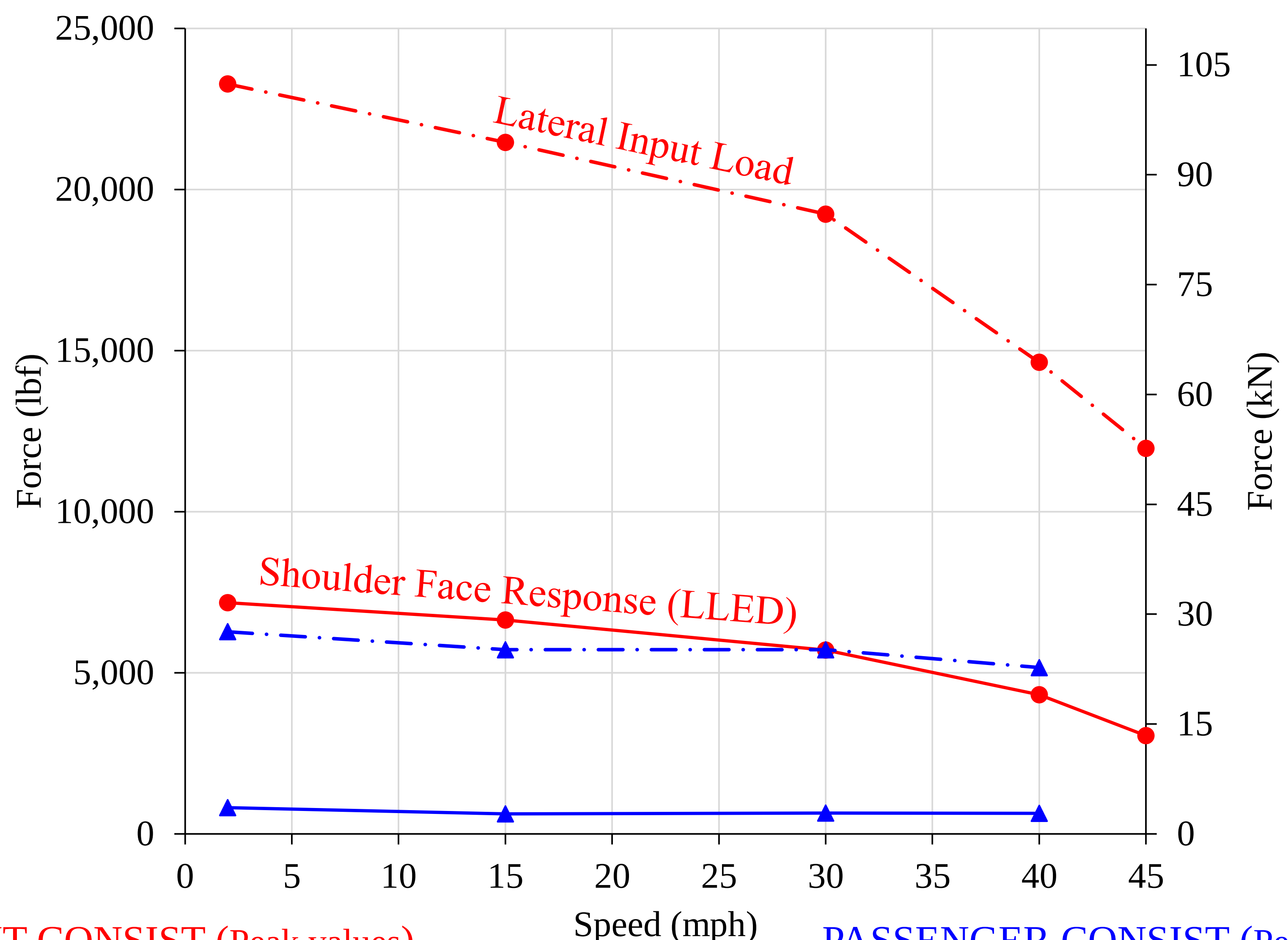



FREIGHT CONSIST (Peak values)

PASSENGER CONSIST (Peak values)

# Lateral Load Restraint

## Curved Track (Low Rail), Passenger and Freight Runs




FREIGHT CONSIST (Peak values)

PASSENGER CONSIST (Peak values)

# Preliminary Field Conclusions

- Lateral loads appear to be primarily distributed among three crossties
  - Vertical load is distributed to five or more crossties based on previous research conducted at UIUC
- Lateral stiffness of the fastening system plays an important role in transferring the lateral load into the shoulder
- As the L/V ratio increases:
  - Lateral bearing restraint forces increase
  - Lateral frictional restraint forces decrease

# Future work

- Measurement of lateral load on revenue service track
- Further laboratory testing
  - Continued tests on PLTM
  - Full-scale track loading system (under construction)
  - Component experiments to better understand the thresholds of plastic damage
- Investigation of alternative component materials
- Application of measurement technology on different fastening systems

# Acknowledgements

U.S. Department of Transportation
Federal Railroad Administration

ASSOCIATION OF AMERICAN RAILROADS


- Funding for this research has been provided by the
  - Association of American Railroads (AAR)
  - Federal Railroad Administration (FRA)
- Industry Partnership and support has been provided by
  - Union Pacific Railroad
  - 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
- For assistance with research and lab work
  - Andrew Scheppe, Harold Harrison, UIUC Machine Shop

**FRA Tie and Fastener BAA Industry Partners:**

UNION PACIFIC BUILDING AMERICA®
BNSF RAILWAY
AMTRAK®
Amsted RPS
Amsted Rail
GIC INGENIERÍA Y CONSTRUCCIÓN S.A. DE C.V.
HANSON
LBFoster CXT Concrete Ties
TTX®

# Questions or Comments?

Brent Williams
Graduate Research Assistant
Railroad Transportation and Engineering Center – RailTEC
email: bwillms3@illinois.edu
Office: (217) 244-6063