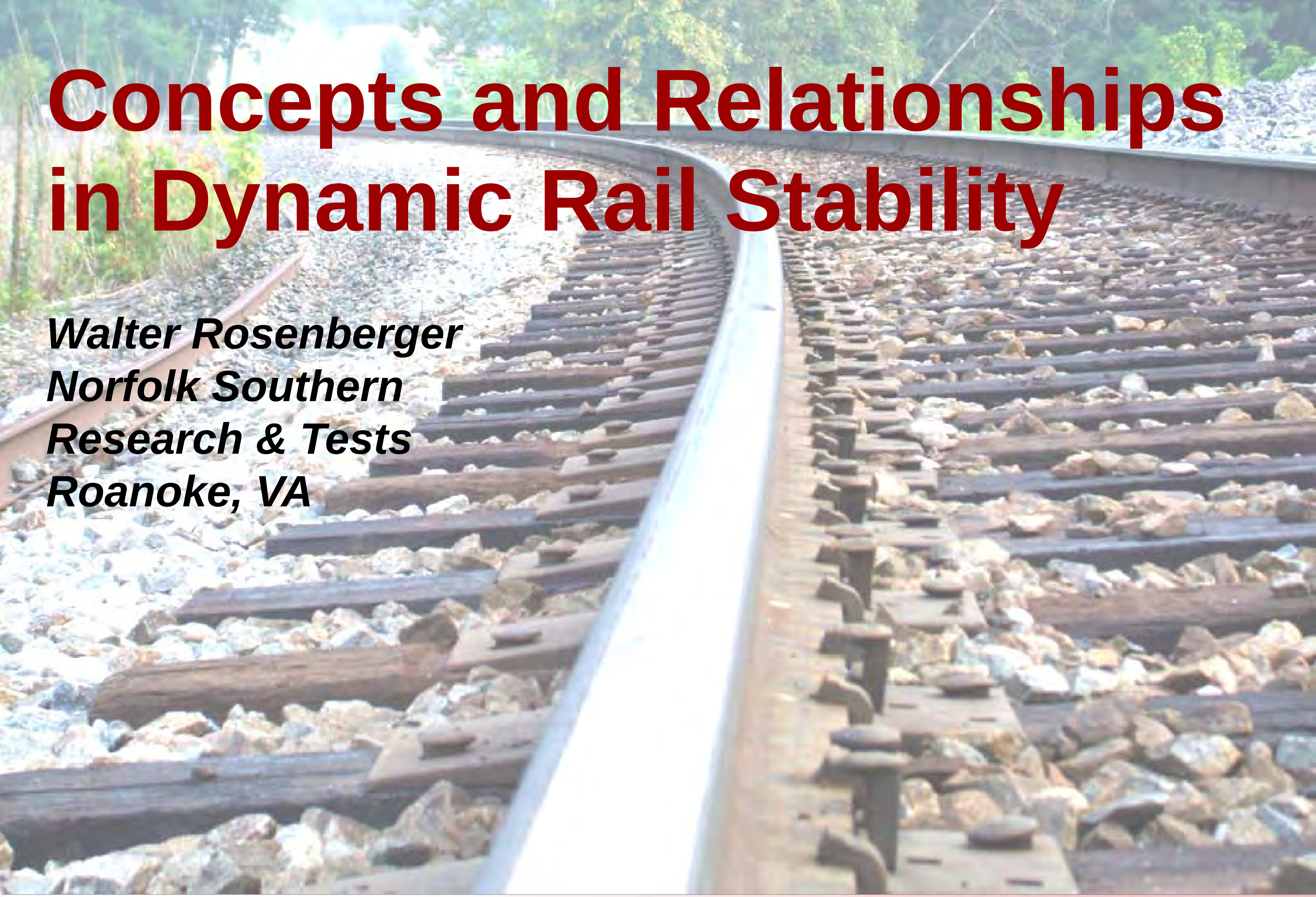

Concepts and Relationships in Dynamic Rail Stability

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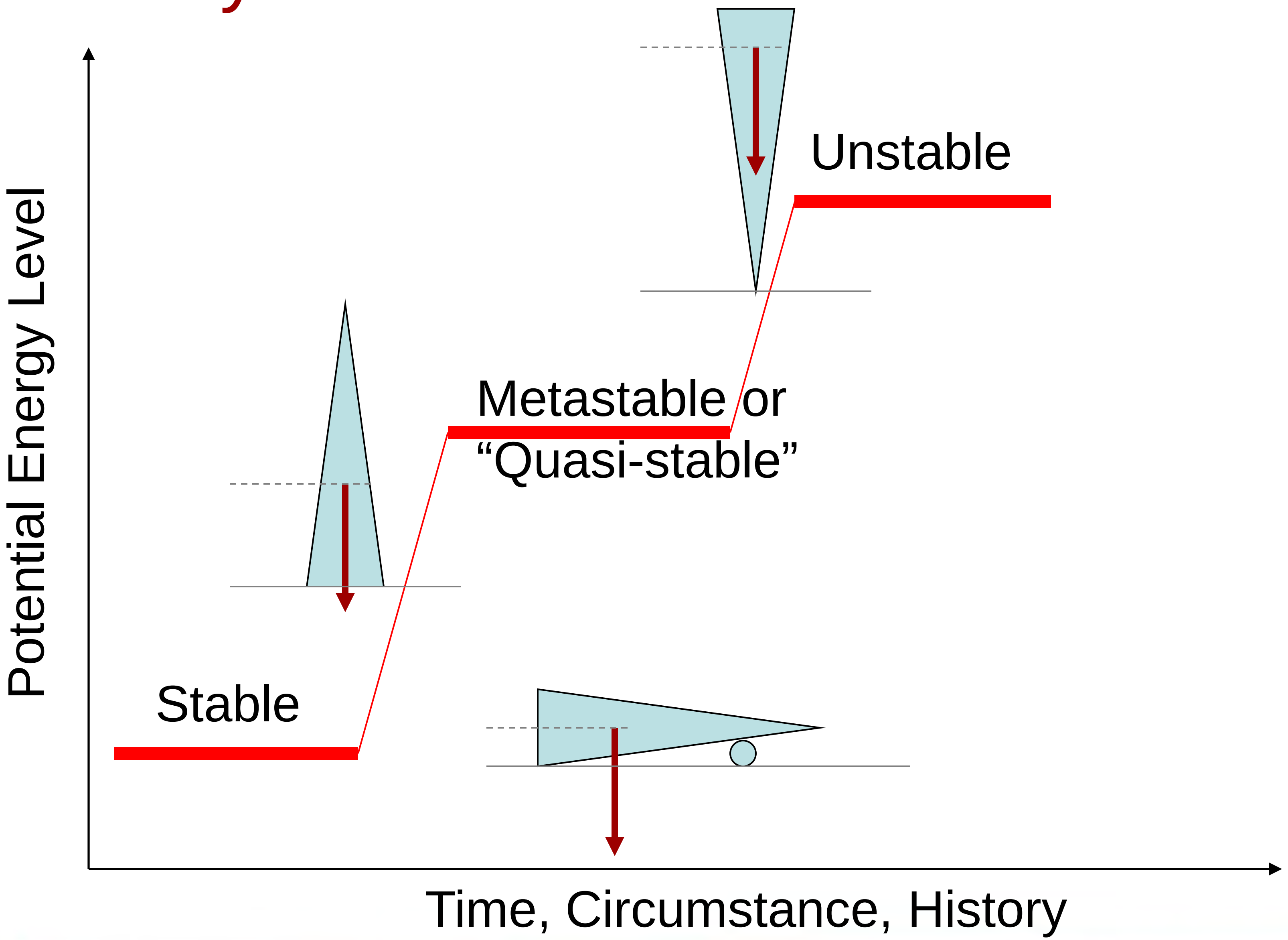
What is Rail Cant?

Introduction

- Definitions
  - "I thought this was going to be about *Rail Cant*."
  - Define "stability" and the stability concept
    - Cant is a physical ***position*** of the rail, at a point in time
    - Stability implies ***risk*** and ***energy*** levels relative to rail roll-over
    - met·a·sta·ble
      - 1. in apparent equilibrium - describes atoms and atomic nuclei in an apparent state of equilibrium, but likely to change to a more truly stable state if conditions change
      - 2. in excited state - describes atoms and atomic nuclei that remain in an excited state for a relatively long time
      - syn. quasi-stable

Stability


Potential Energy Level
Unstable
Metastable or
“Quasi-stable”
Stable
Time, Circumstance, History

Introduction

- Why is this a problem? What has changed?
  - Load environment – higher axle loads, greater tractive loads, greater lateral loads
  - Equipment – better high speed stability on tangent track; not so much in curving performance
  - Premium rail steel – perhaps energy formerly wearing the running surface is going into the track structure?

Four Aspects of Rail Stability

- Physics: What are the forces on the rail? Where do they come from? What physical conditions cause rail to deflect/cant?
  - Wheel profiles, rail profiles, contact patch location, rolling radius differential, differential lubrication, warped trucks, etc.
- Manifestations: What happens to the track structure as a result of these forces?
  - Tie plate cutting, rail seat abrasion, rail wear (gage and top), rail cant, open gage, raised spikes, etc.

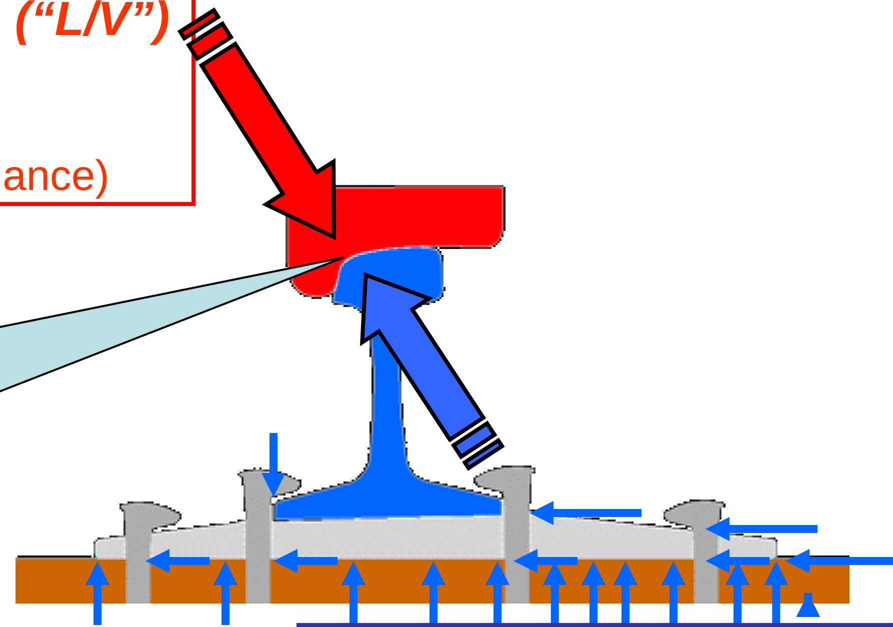
Four Aspects of Rail Stability (continued)

- Remediation: How do you fix a rail stability problem?
  - Recognize that a problem may exist
  - Take action***s*** that reduce Gage Spreading Forces
  - Corrective grinding (for profile) ***and*** tie adzing/ renewal ***and*** corrected track gage (not too tight)
  - Doing ***one*** thing will upset the metastable condition that has developed
- Prevention
  - TOR friction modifiers + appropriate gage face lube, grinding for profile, premium rail fasteners, improved equipment health as measured by wayside detectors

A Conceptual Model of Rail Cant

Origin and Effects

Input Force System ("L/V")
- Equipment condition
- Wheel/mate profiles
- Speed (over/under balance)



Wheel/Rail Interface as a Transfer Function
- Wheel and mate wheel profiles
- Rail profiles
- Lubrication
- Rail cant, effective gage

Strength of Track System
- Plates, crossties, ballast
- Spikes/fasteners
- Torsional stiffness of rail section

feedback loop

Results
- Gage opening
- Rail cant
- Static (permanent deformation)
- Dynamic (elastic deformation)

Input Forces

- Truckside L/V is the usual parameterization
  - Usually requires more than one truck to roll rail
- Equipment condition
  - Stiff-turning trucks
  - Warped trucks
  - Wheel profiles – asymmetric, hollow worn – rolling radius differential
- Speed
  - Over balance speed
  - Under balance speed

Input Force System ("L/V")
- Equipment condition
- Wheel/mate profiles
- Speed (over/under balance)

Input Conditions

Input Force System ("L/V")
- Equipment condition
- Wheel/mate profiles
- Speed (over/under balance)

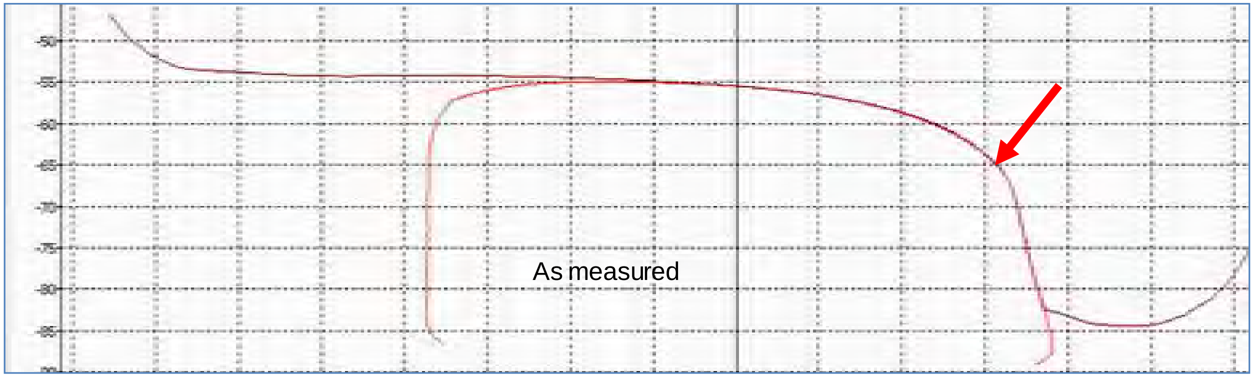


Figure A6. Common Worn Wheel Contact on a Measured High Rail Profile

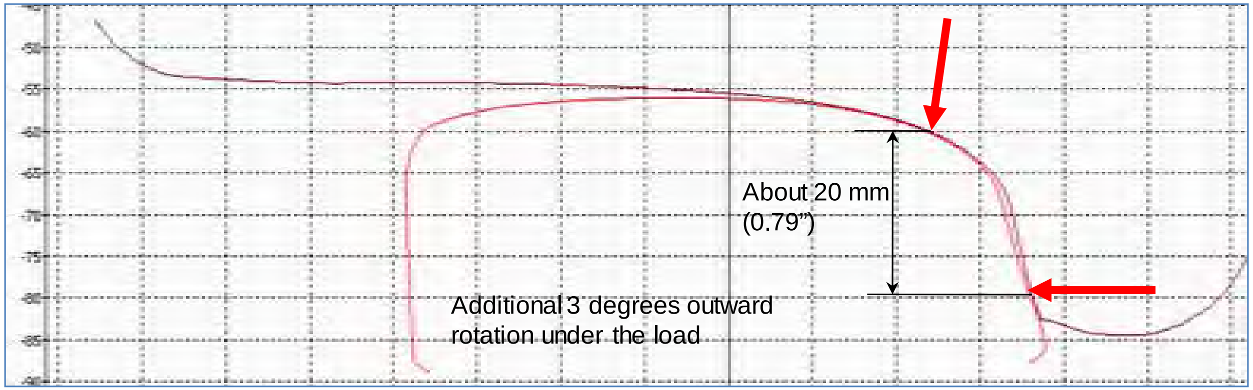


Figure A7. Common Worn Wheel Contact on a Measured High Rail Profile with Assumed 3 Degrees of Additional Outward Rotation

courtesy Dave Davis, TTCI

Strength of Track System

- Usually requires more than one truck to roll rail
- Vertical strength
  - Tie plates, crossties, ballast
- Lateral strength
  - Tie plate shoulders, spikes, crossties, ballast
  - Normally, ***all*** lateral wheel/rail forces are ***outward***
- Torsional strength
  - Gage line spikes
  - Rail section stiffness
  - Rail B/H (base/height) is the usual parameterization

Strength of Track System
- Plates, crossties, ballast
- Spikes/fasteners
- Torsional stiffness of rail section

Results (all in the track)

Results
- Gage opening
- Rail cant
- Static (permanent deformation)
- Dynamic (elastic deformation)

- Gage opening
  - outward rail cant, and translation
- Static (permanent deformation)
  - Plate cutting into crosstie (may be convex) or rail seat abrasion
  - Raised/broken gage spikes
- Dynamic (elastic deformation)
  - Compliance in ties, ballast, and clearances
- Strength vs. Stability

Wheel/Rail Interface "Transfer Function"

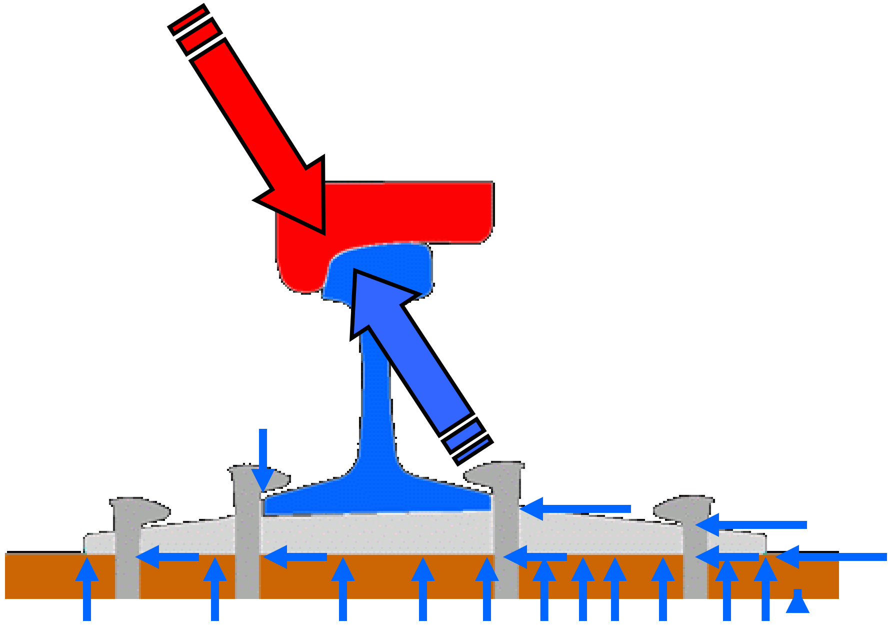
- Transfer *Input Forces* into *Track Structure*
- Comprising
  - Wheelset profiles
  - Lubrication
  - Rail profiles (*)
  - Profile cant (*)
  - Effective gage (*)
- (*) These *affect* the transfer function, and are themselves *effects* of it.

Wheel/Rail Interface as a Transfer Function

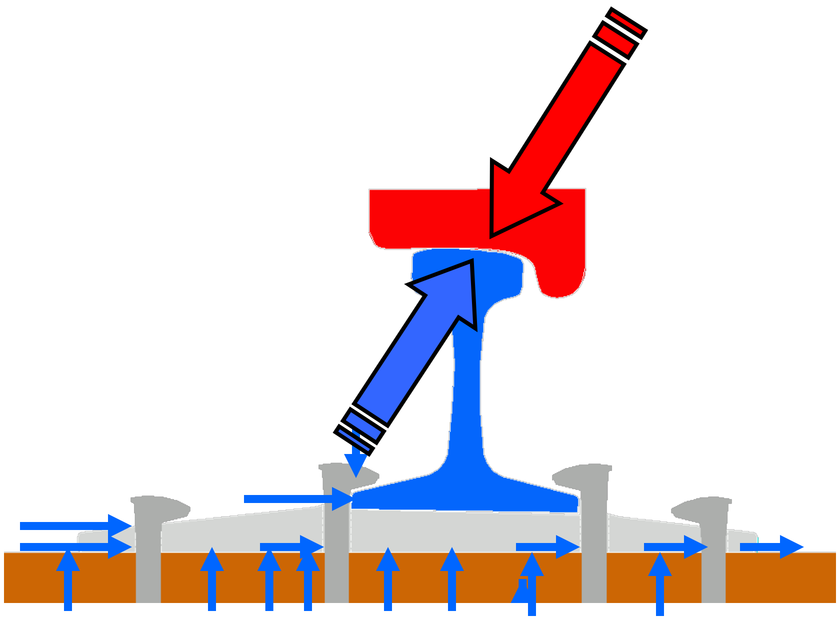
•Wheel and mate wheel profiles
•Rail profiles
•Lubrication
•Rail cant, effective gage

Rail Cant – High Rail Mechanisms

- Gage corner contact tends to keep rail upright, less cant
- Rapid disintegration as 2-pt contact develops
- Main contact patch moves to field side
- B/H becomes a binomial function
- After contact patch friction becomes saturated, lateral force goes to flanging contact, at a lower height, H

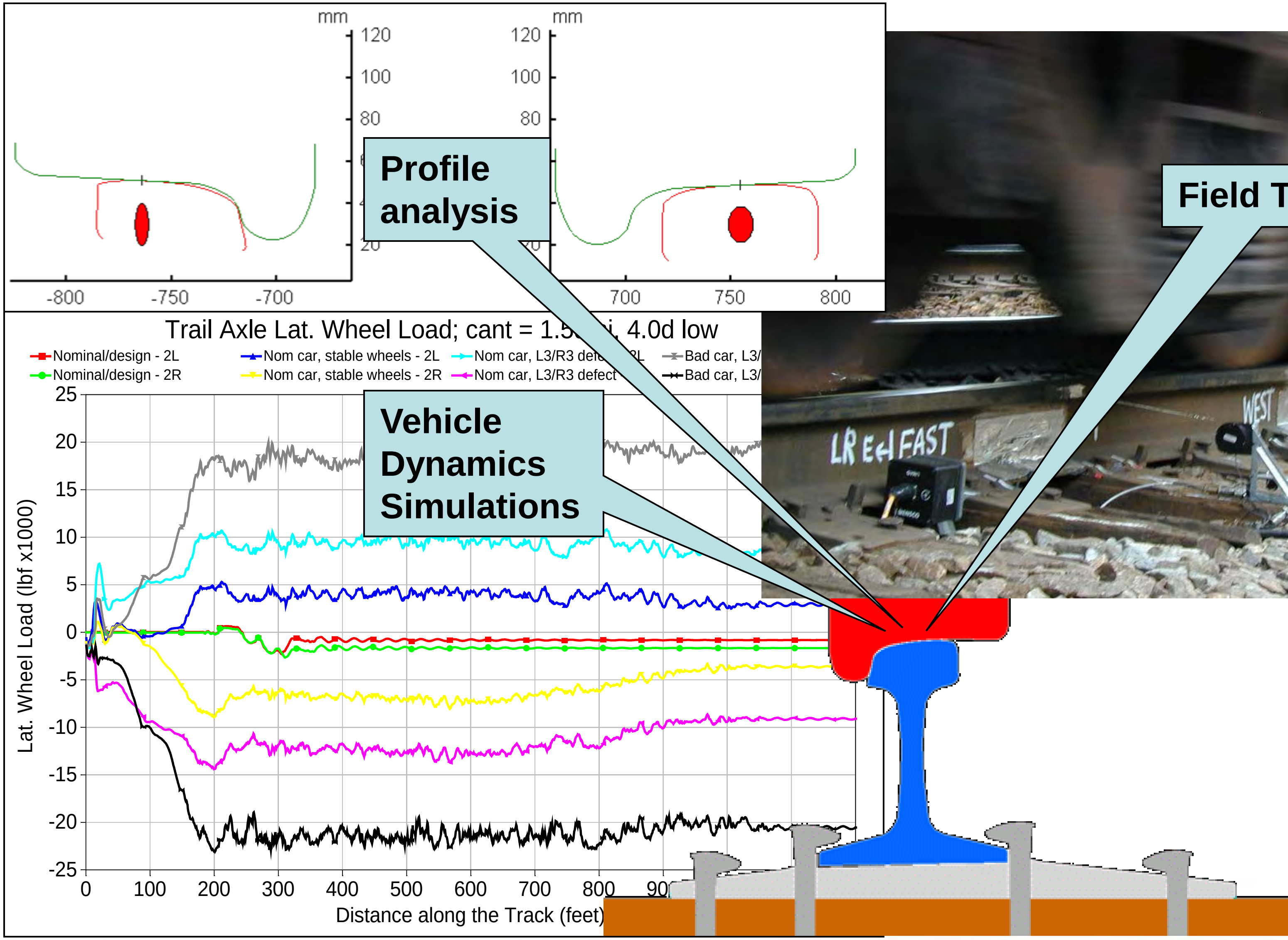


Rail Cant – Low Rail Mechanisms



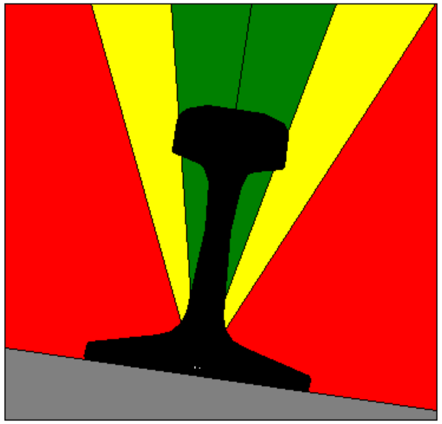
- Try to keep contact centered over rail
- High Rail likely influences Low Rail more than Low Rail influences High Rail
- Gage side contact: < rolling radius diff, < steering, > lateral forces; but > B/H
- Field side contact: > rolling radius diff, > steering, < lateral forces ; but < B/H
- Dynamic cant:
  - self defeating: > L/V
  - self correcting: > B/H
  - which one prevails?

Rail Stability Analysis



Final Thoughts

- What is an acceptable *Stability Level* of the rail?
  - as contrasted with *Strength* of the track system
- How do you measure rail stability?
- How do you fix – improve – rail stability?



Orientation	Alert	Alarm
Inward	4.6	5.6
Outward	-1.8	-2.8

Table 1 – FRA Rail Cant Thresholds

References

- R.R. Newman, et al, *125-ton Double Stack Derailment Prevention*, Double Stack Derailment Task Force/ Association of American Railroads, June 1991
- S.E. Mace, D.A. DiBrito, R.W. Blank, L.S. Keegan, M.G. Allran; *Effect of Wheel and Rail Profiles on Gage Widening Behavior*; Proceedings of the 1994 ASME/IEEE Joint Rail Conference
- Joe Kalousek, *Rolling Radius Difference – Do We Appreciate Its Significance?*, Technical Report CSTT-VTS-54-AAR, Wheel Rail Interface Conference, Chicago, May 2001
- Matthew Dick, *Cumulative Track Geometry Degradation using VAMPIRE Automation,* Wheel Rail Interface Infozone, Chicago, May 2009