Proactive Wheel/Rail Interface Study on a Light Rail System with Independent Rotating Wheels

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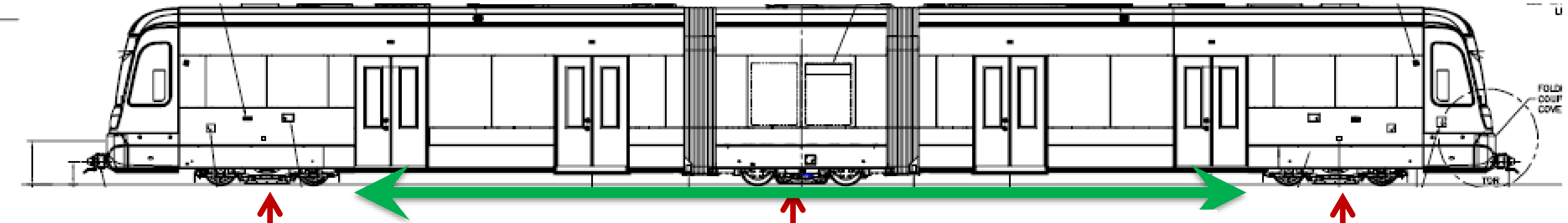
Key Motivation for the Study

- Observations:
  - ➢ Multiple contact bands on the rail at curves
  - ➢ Increased wayside train vibration levels
  - ➢ Uneven wheel wear
- Proactive initiative:
  - ➢ Optimize wheel rail interface before introducing 152 new LRVs

Background

- Sound Transit has 62 70% Low Floor LRVs built by KinkiSharyo (KI)
- Siemens is building 152 new LRVs for Sound Transit and delivered the first car earlier this month.
- Sound Transit is expanding the Link Light Rail alignment over the next couple of decades

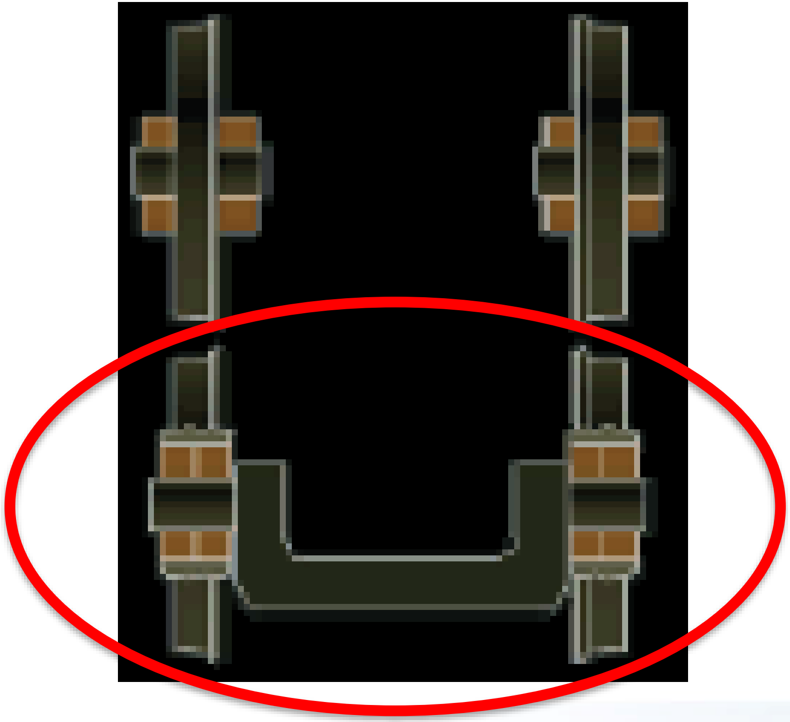
Introduction – 70% Low Floor LRV



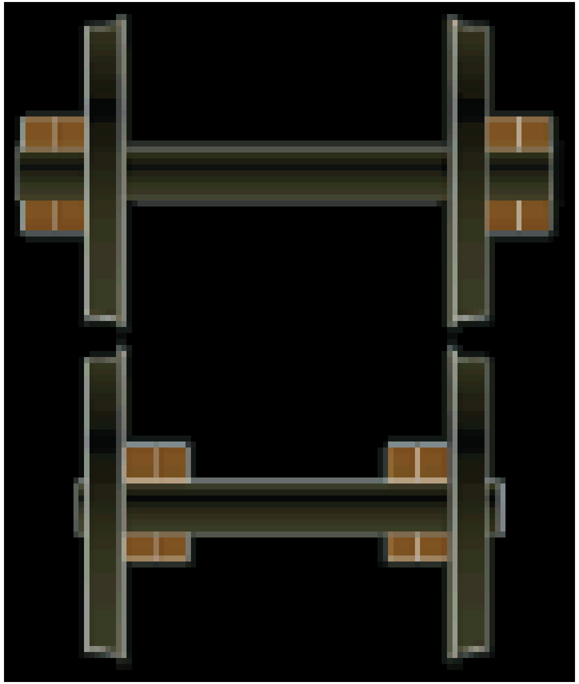
IRW = Independent Rotating Wheels

Trailer Truck Axles

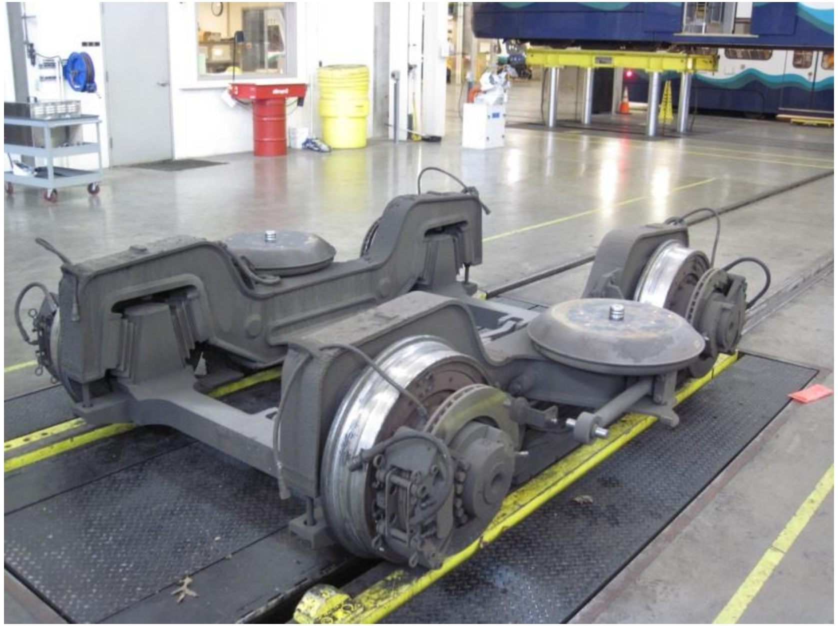
Independent Rotating Wheels



Solid Axles



Independent Rotating Wheels (IRW)

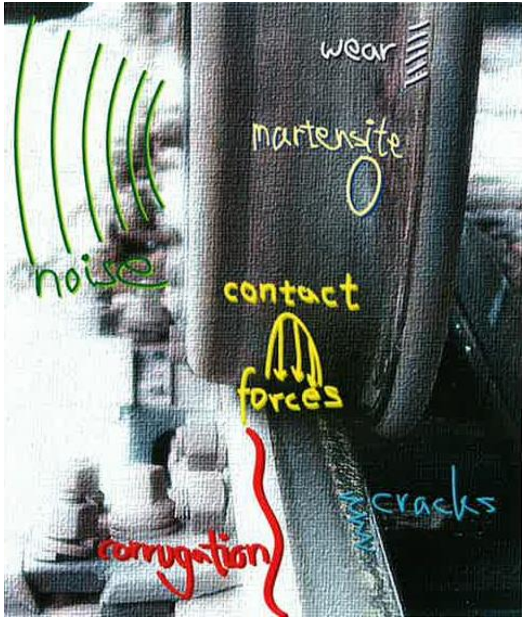


Performance Metrics of Interest for Optimization

- Safety (#1 Priority)
- Maintenance (Wheel and rail wear)
- Environmental (Wayside noise and vibration)
- Passenger comfort (Ride quality)

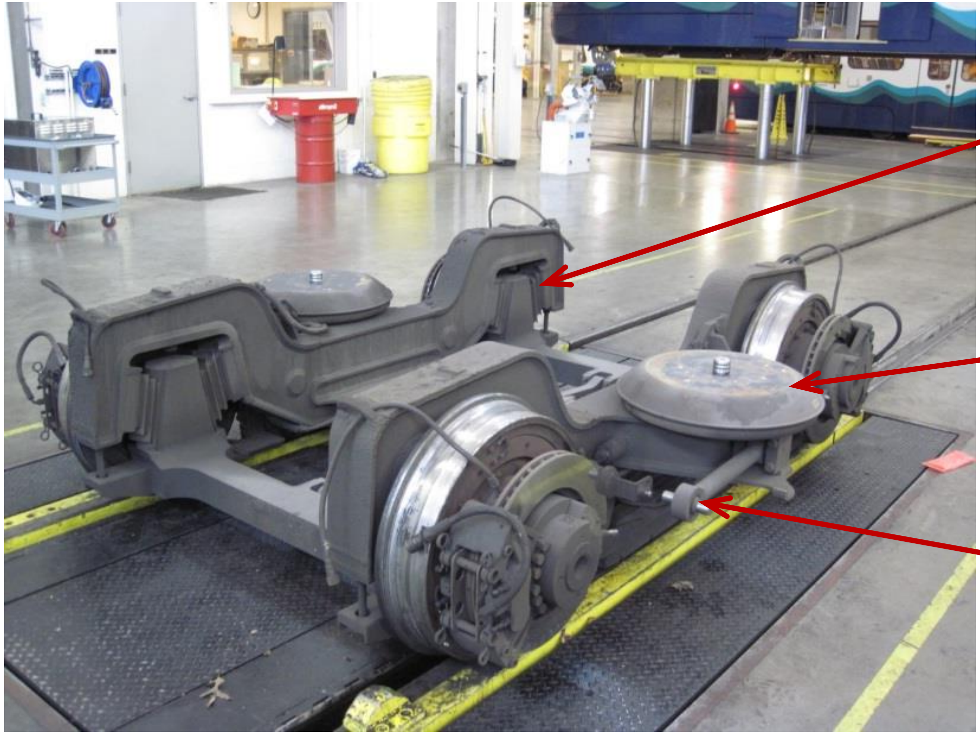
Factors Influencing Performance Metrics -1

Wheel/Rail Interface



- Wheel/Rail profile match
- Wheel taper and flange angle
- Surface smoothness
- Lubrication/friction modifier
- Track geometry

Factors Influencing Performance Metrics - 2



Primary Suspension

Secondary Suspension

Bolster

Dynamic Interaction between Wheel & Rail

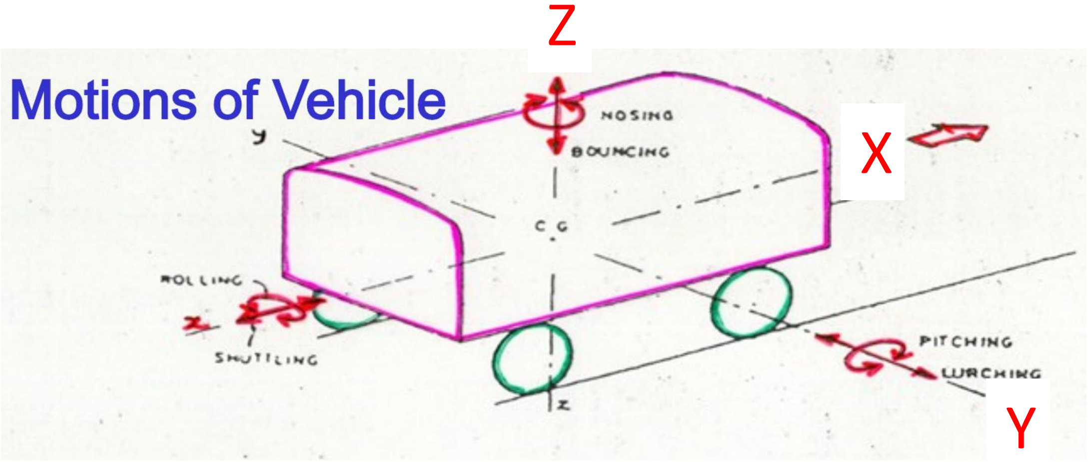
Vertical direction

- Wheel displacement
- Rail displacement
- Relative displacement with wheel & rail
- Track irregularity

Lateral direction

- Wheel & rail displacement
- Rail displacement
- Track irregularity
- Contact and creep forces
- Flange pressure
- Rail tilting & Rail/flange gap

6 Modes of Oscillation for LRVs



Axis	Mode of Oscillation	
	Linear	Rotational
X	Shuttling	Rolling
Y	Lurching	Pitching
Z	Bouncing	Nosing (Yaw)

Power Truck: Hunting = Rolling + Nosing

IRW Truck: Mostly Lurching + Some Nosing

Reference: Rail Wheel Interaction Presentation by Nilmani, Prof. Track

Vehicle Defects and Oscillations

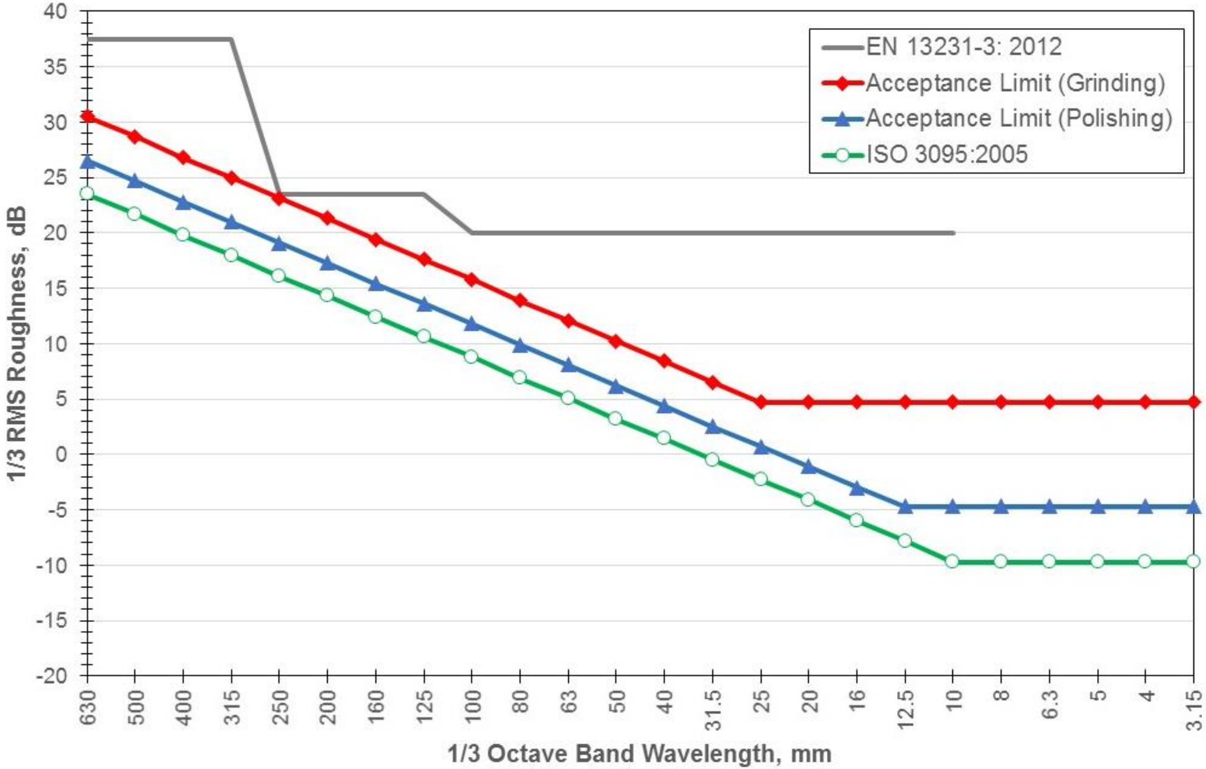
Vehicle Defect	Oscillatory Motion
Worn wheel	**Hunting, Nosing, Lurching**
Ineffective spring	**Bouncing, Pitching, Rolling**
Coupling	Shuttling, Nosing
Side bearer clearance	Rolling, Nosing
Ineffective pivot	Nosing

Reference: Rail Wheel Interaction by Nilmani, Prof. Track

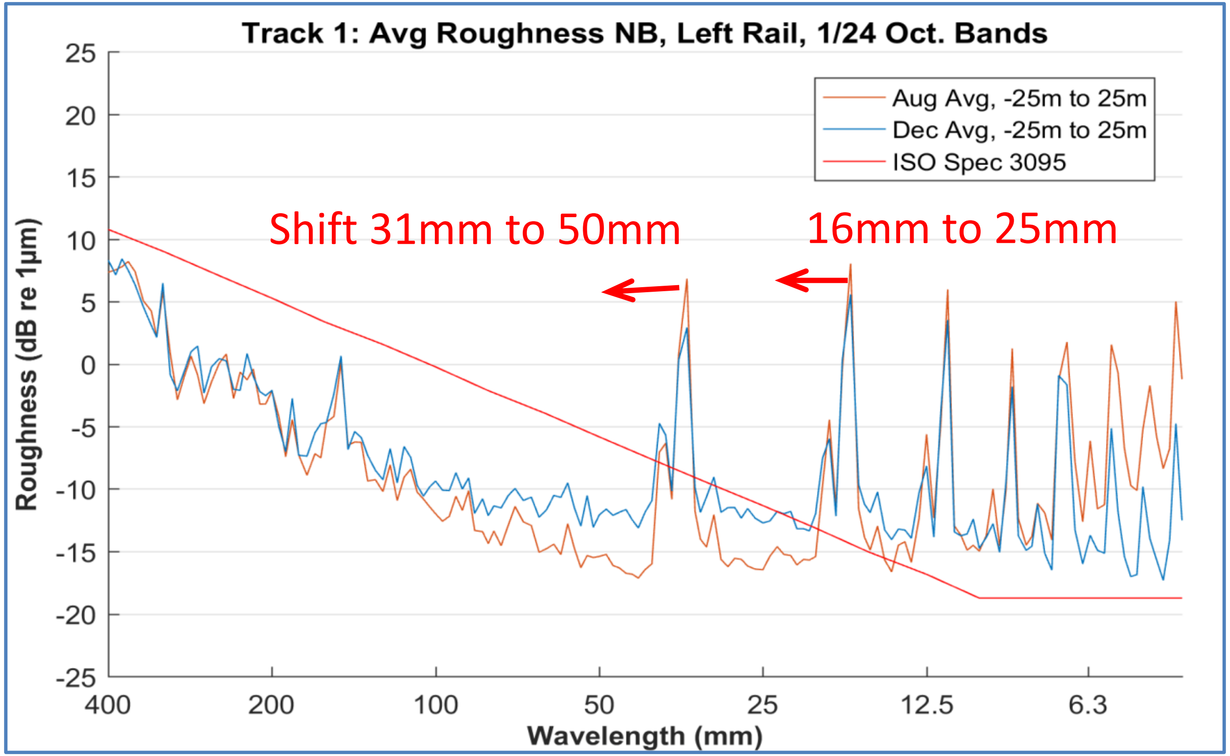
Sound Transit Wheel Rail Study Approach

- Measure wheel and rail wear
- Develop vehicle models and perform parametric study
- Grind rails to a new specification
- Perform field trials using test wheels and vehicle-mounted lubrication systems
- Optimize wheel/rail match and friction management

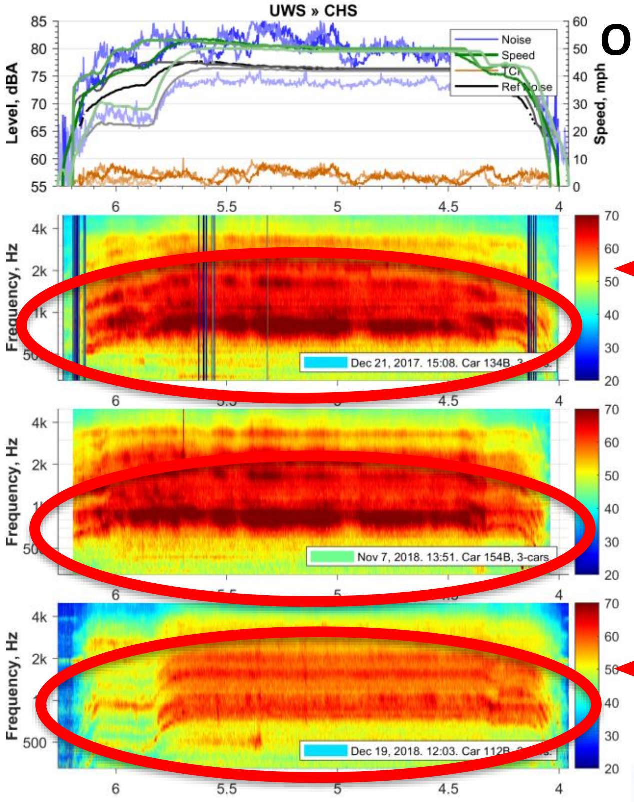
ST's New Rail Grinding Specification



ST's New Rail Grinding Specification



Onboard Noise - Effect of Grinding

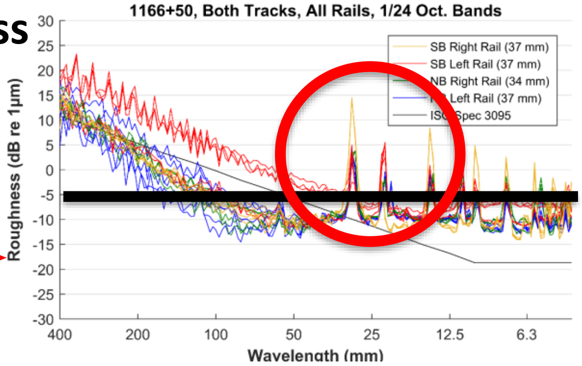


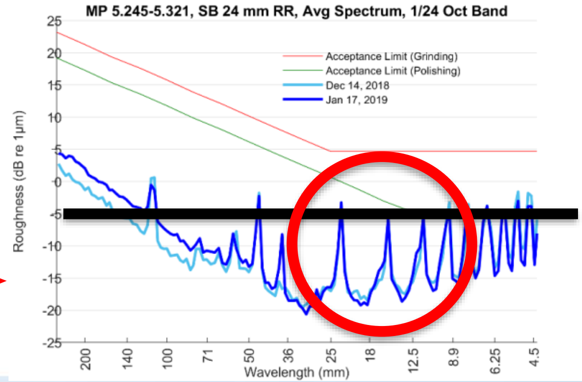
Onboard noise Spectra

Rail roughness

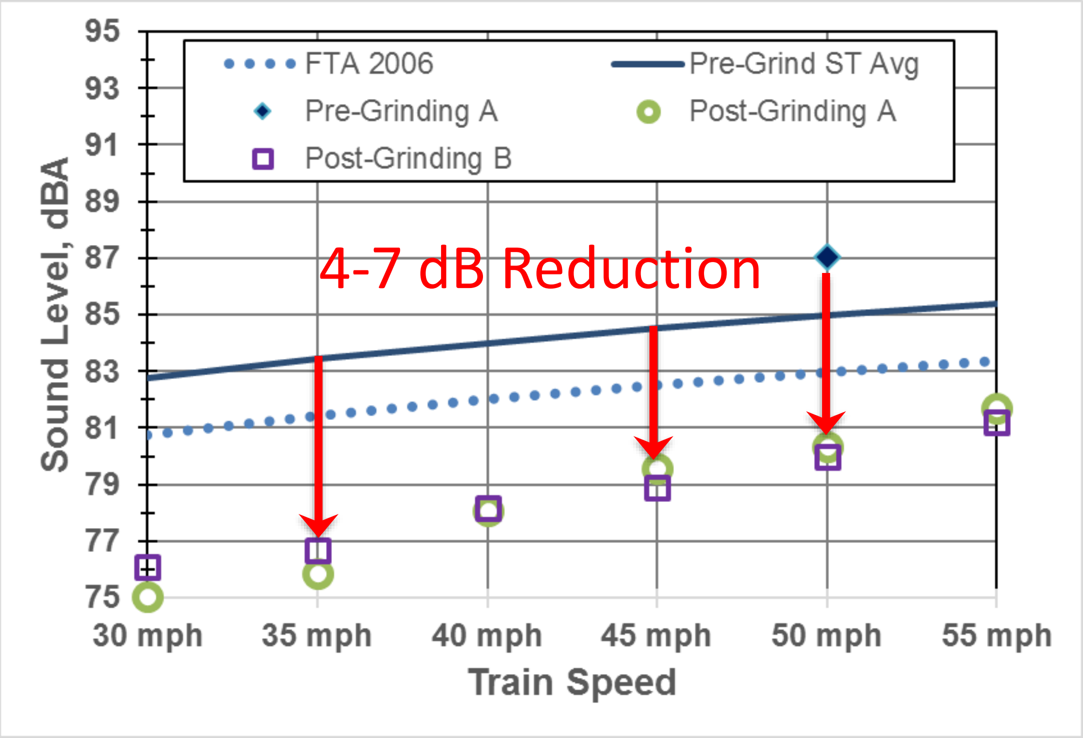
Pre-Grinding

Post-Grinding



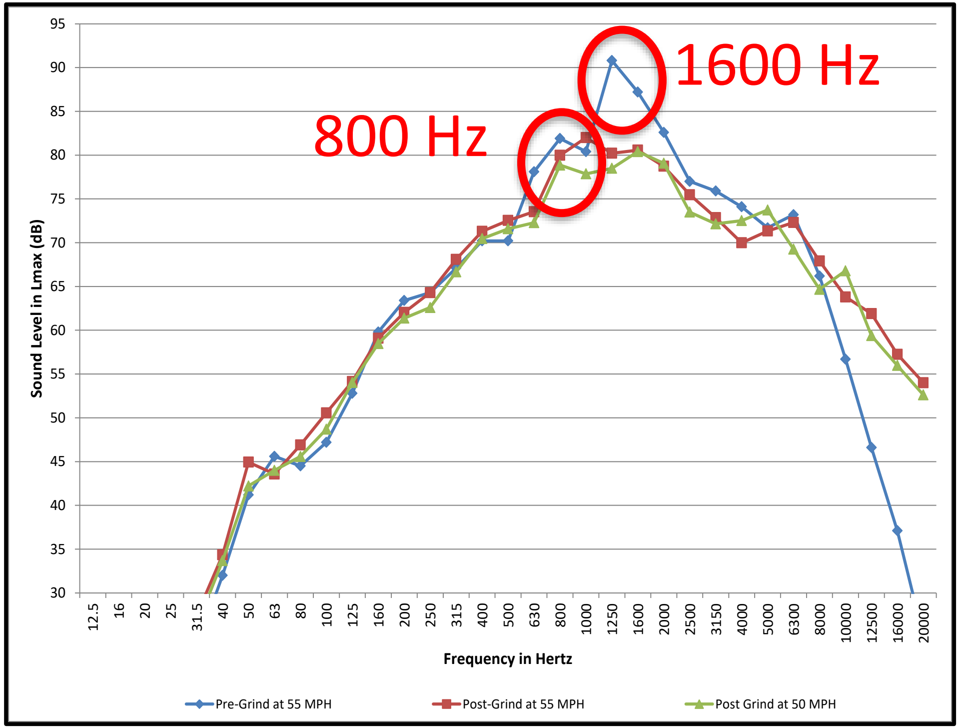


Train Noise Pre- & Post-Grinding

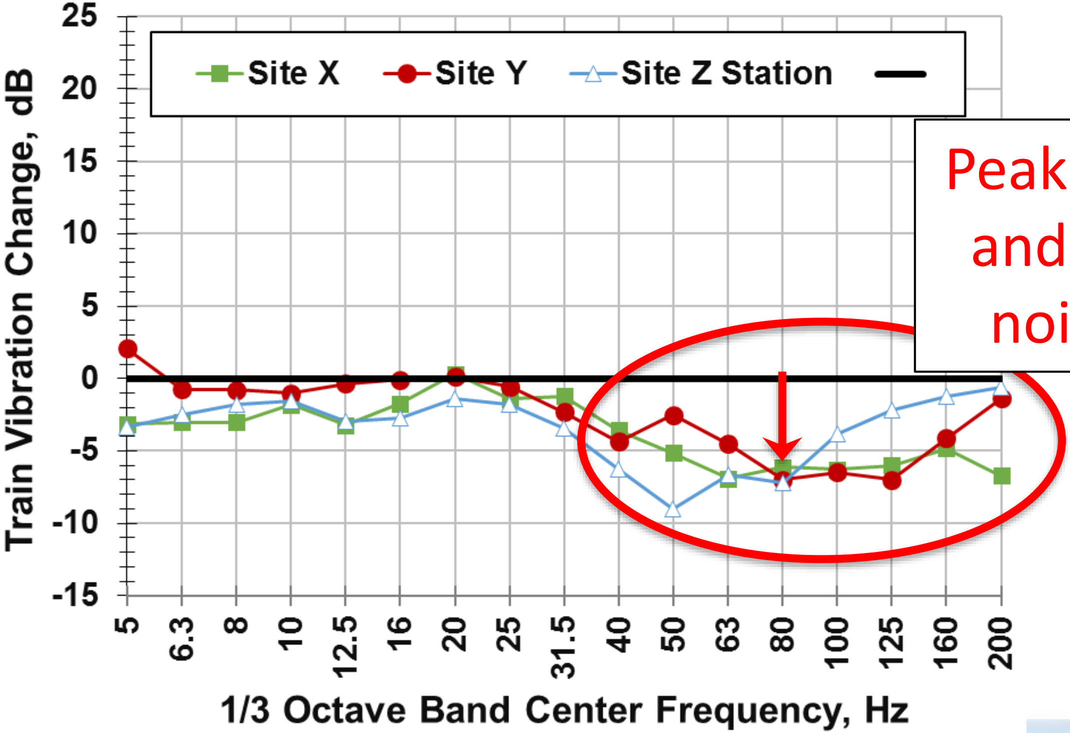


Normalized
Draft SEL
1-car train 50 feet
B&T Tracks

Train Noise Spectrum Pre- & Post-Grinding



Train Vibration Reduction Post-Grinding



Peak train vibration and groundborne noise frequency

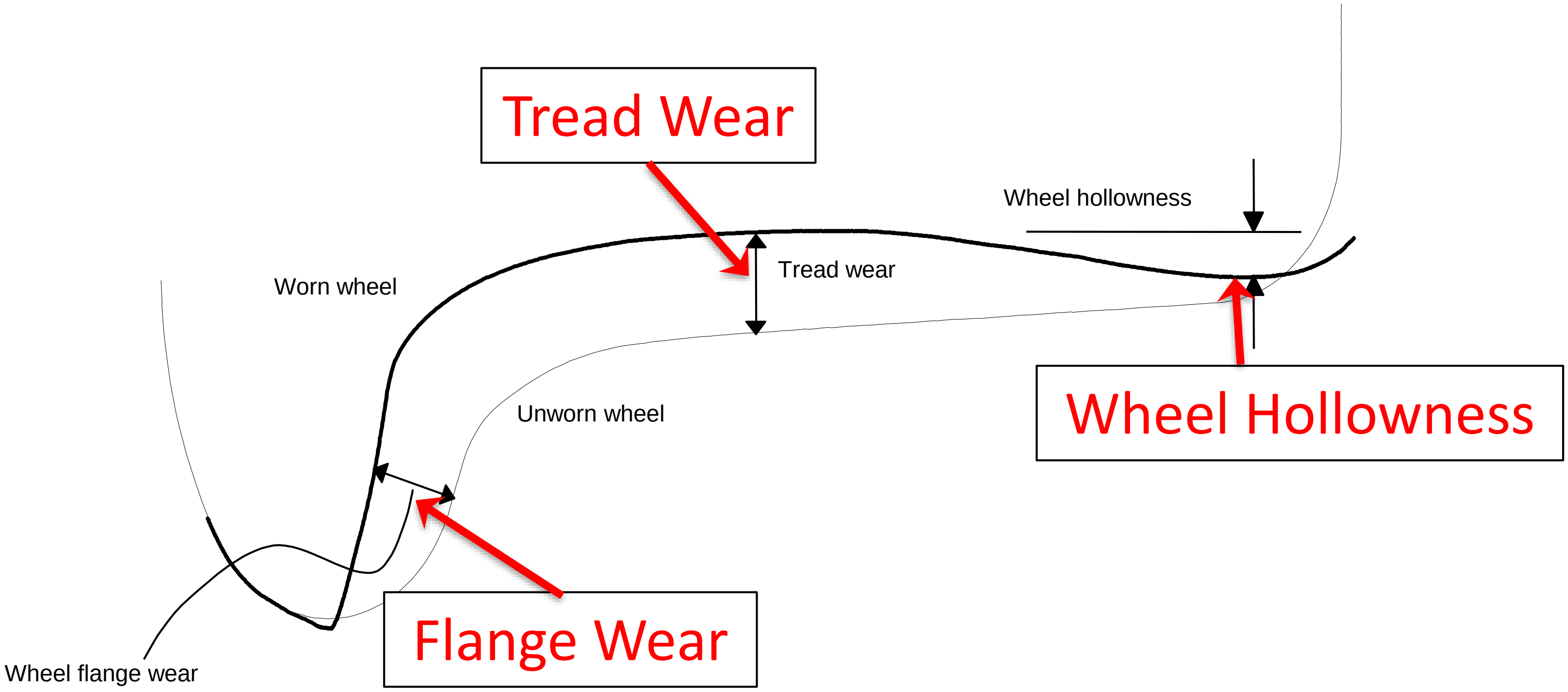
Multiple Contact Bands

2 – Contact bands

3 – Contact bands

4 – Contact bands

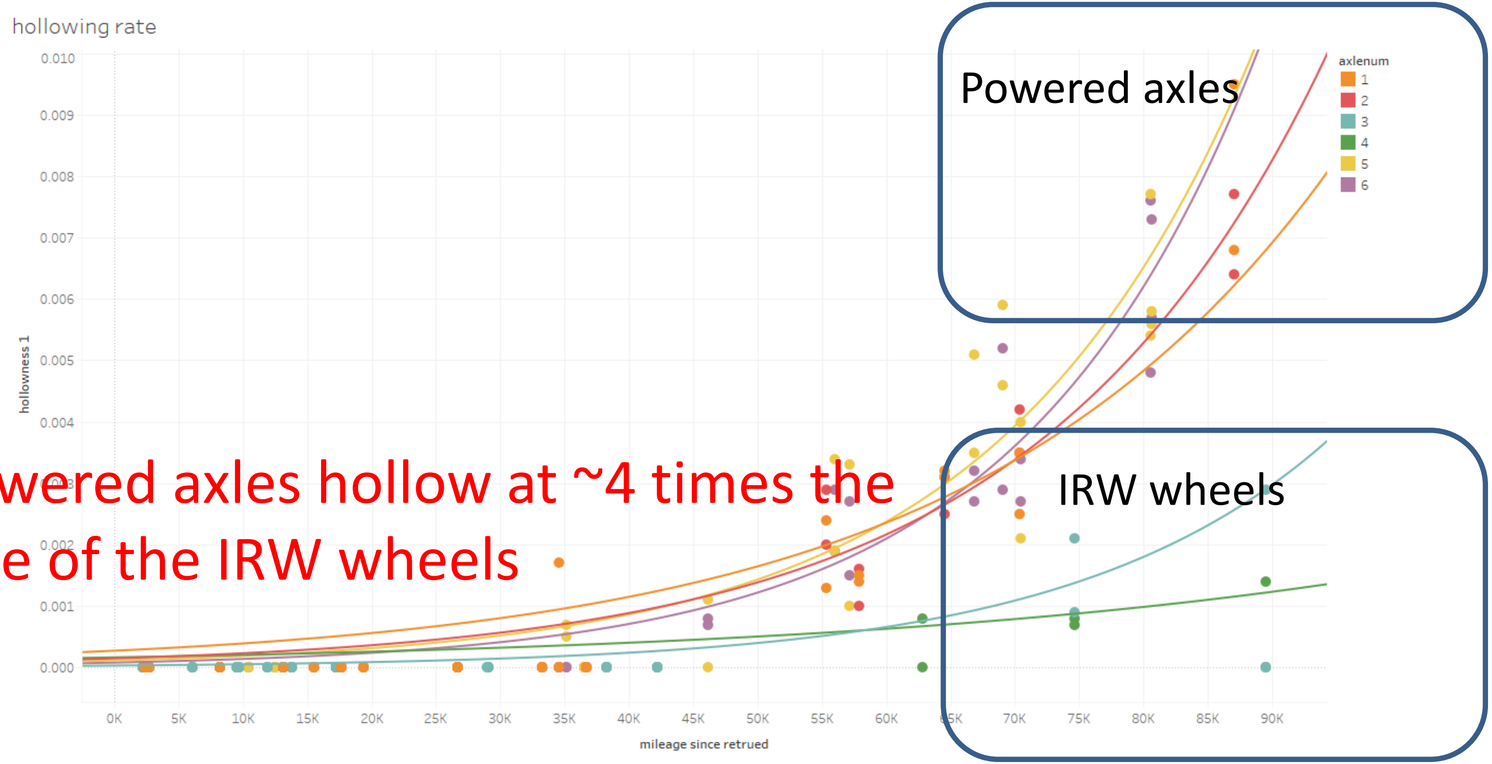
Key Wheel Wear Issues



Wheel Taper of 70% LFLRVs in US

System	Rail	Wheel taper (1 in)
Portland	115RE	30
Portland	Ri59	30
Newark	115RE	20
Hudson-Bergen	115RE	20
Santa Clara	115RE	32
Santa Clara	Ri59	32
San Diego	115RE	40
Houston	115RE	40
Boston	115RE	Formerly 40 now 20
Boston	149GCR	Formerly 40 now 20
Sound Transit	115RE	20

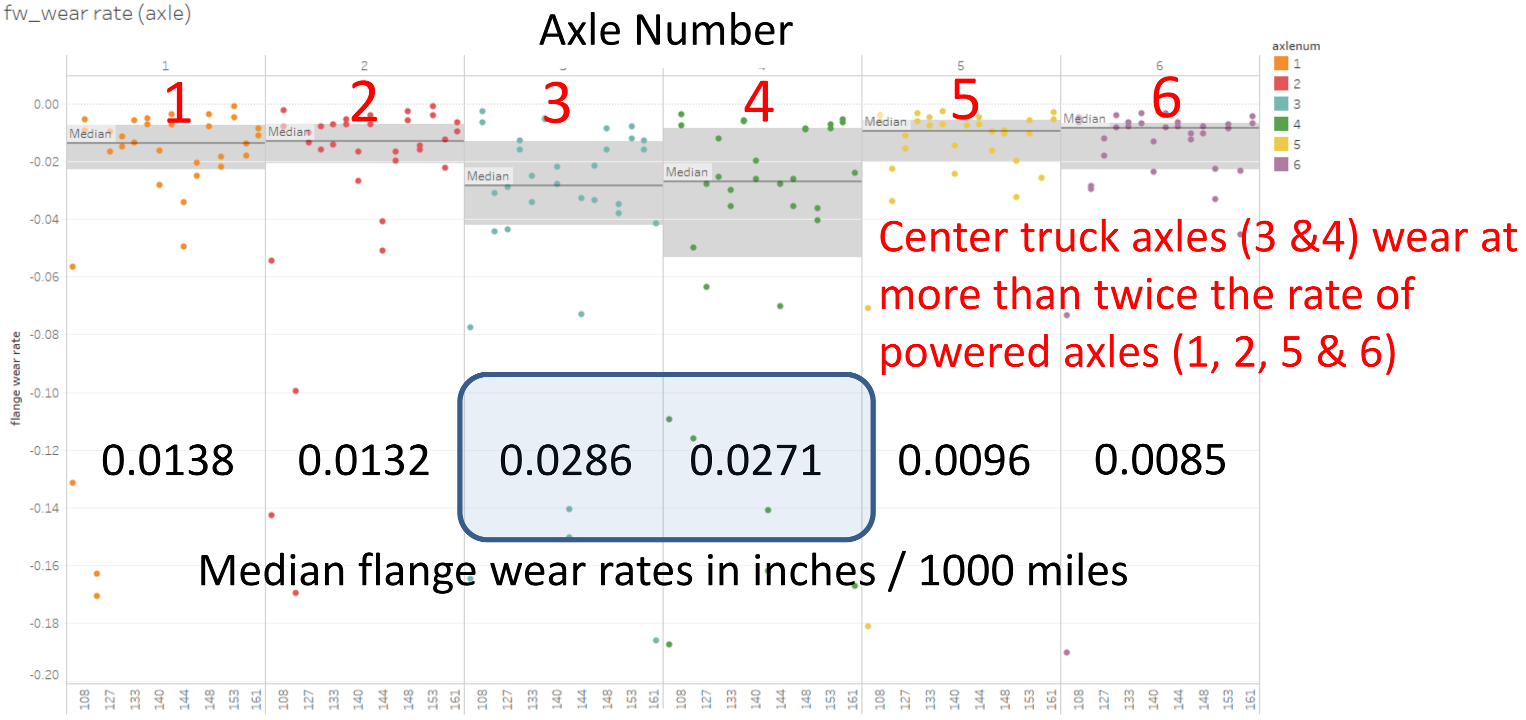
Wheel Wear Measurements - Hollowing



Powered axles hollow at ~4 times the rate of the IRW wheels

Mileage since retrued vs. hollowness 1. Color shows details about axlenum. Details are shown for side. The view is filtered on axlenum and side. The axlenum filter excludes Null. The side filter keeps L and R.

Flange Wear Rate



Flange wear rate for each carnum broken down by axlenum. Color shows details about axlenum ... on axlenum and side. The axlenum filter excludes Null. The side filter keeps L and R.

Measured Wheel Wear Summary

- Powered truck wheels showed higher hollowness
- Center truck wheels showed higher flange wear
- Center truck wheel wear showed some asymmetry

ST LRV Primary Suspension Systems

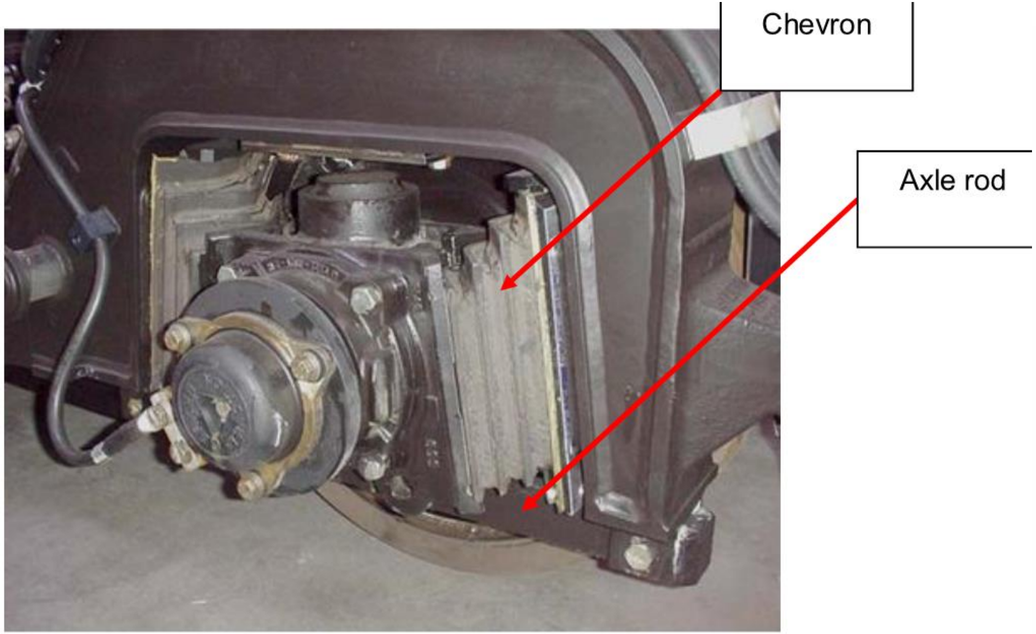


Figure 14: Power truck primary suspension – chevron.

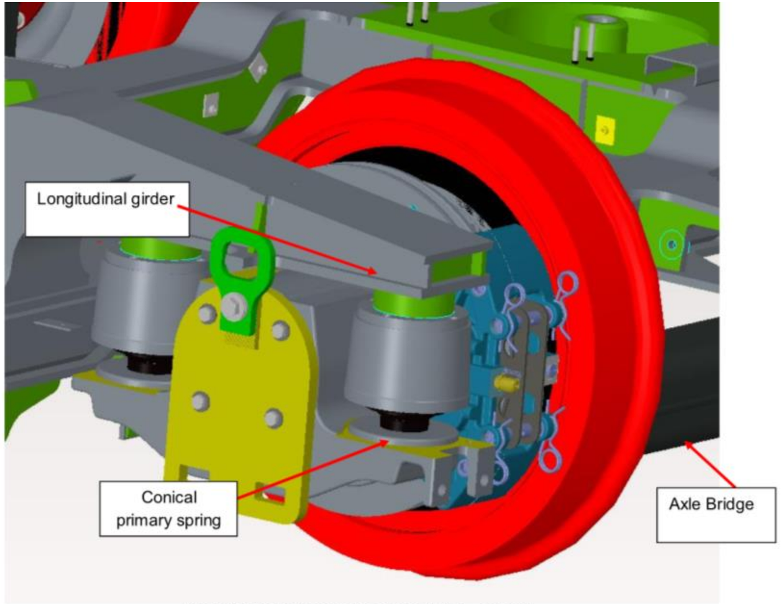


Figure 16: Center truck primary suspension – conical.

ST LRV Secondary Suspension Systems

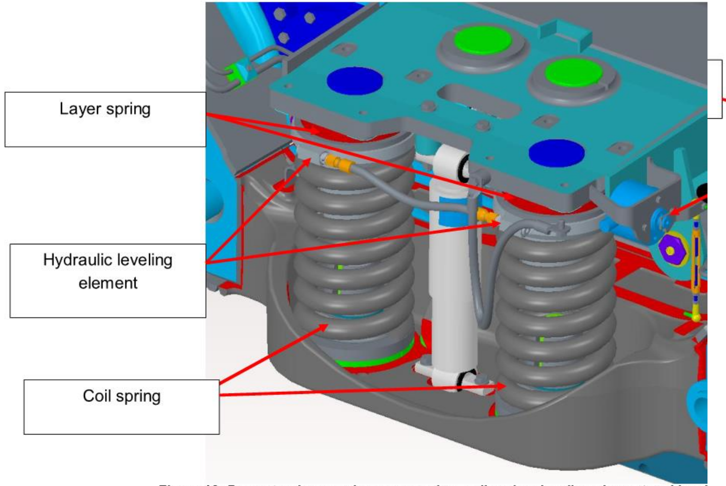


Figure 18: Power truck secondary suspension, coil spring, leveling element and level

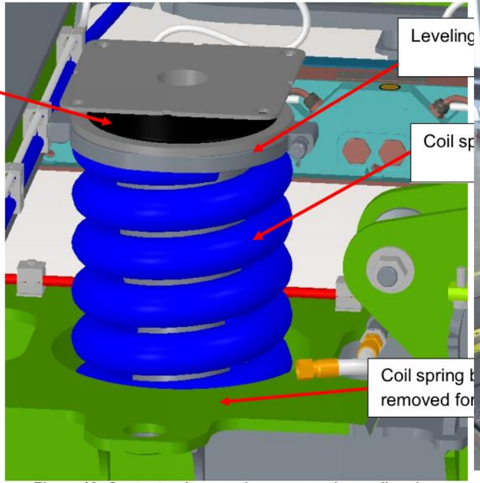
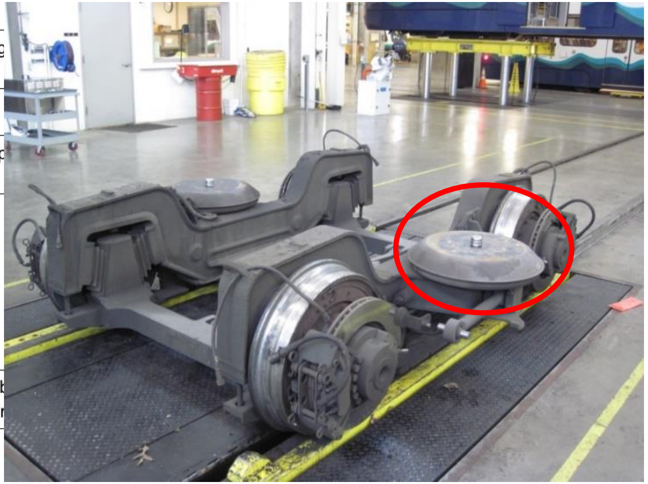
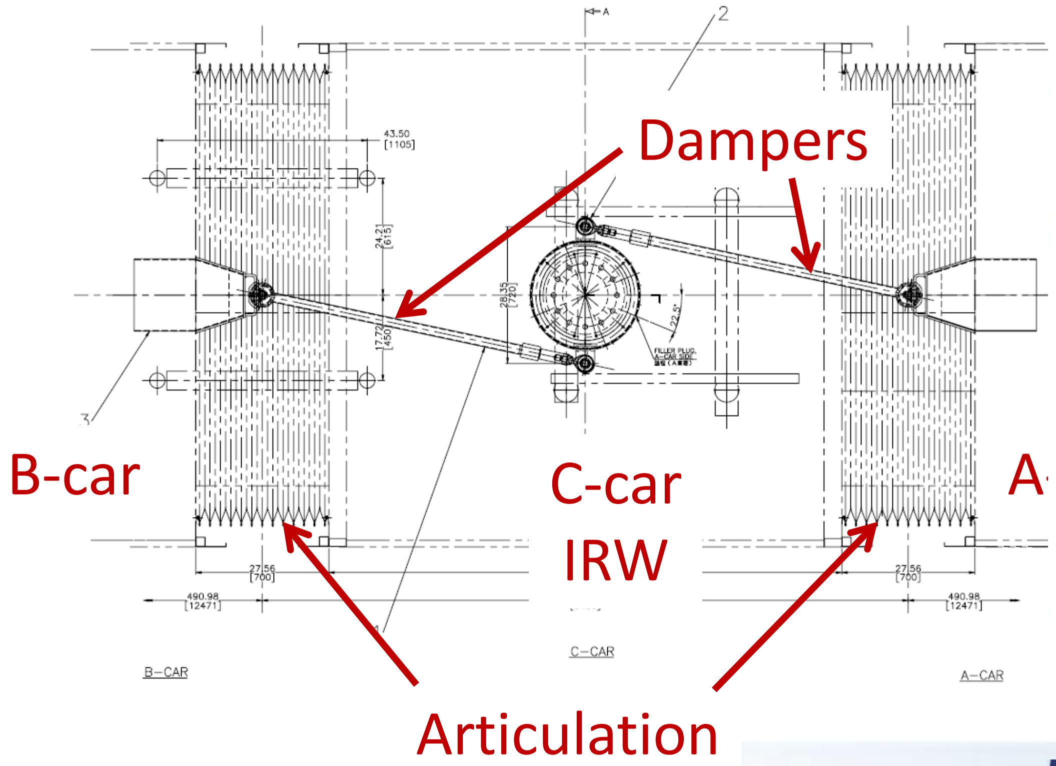


Figure 19: Center truck secondary suspension, coil spring



Examples of Dampers on Roof and Truck



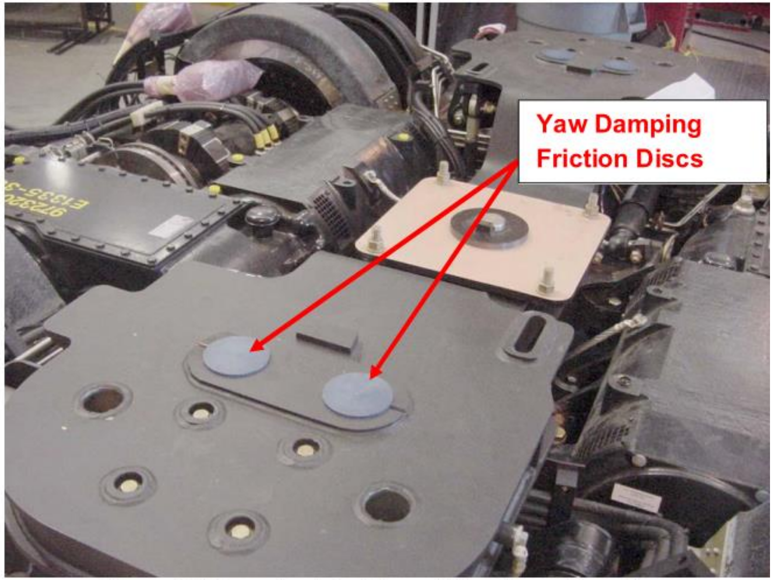
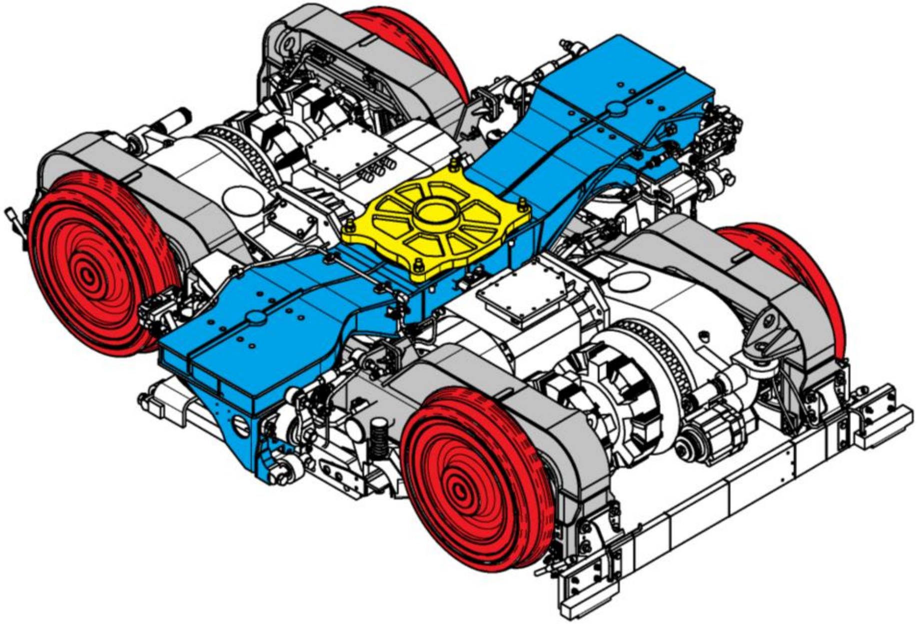


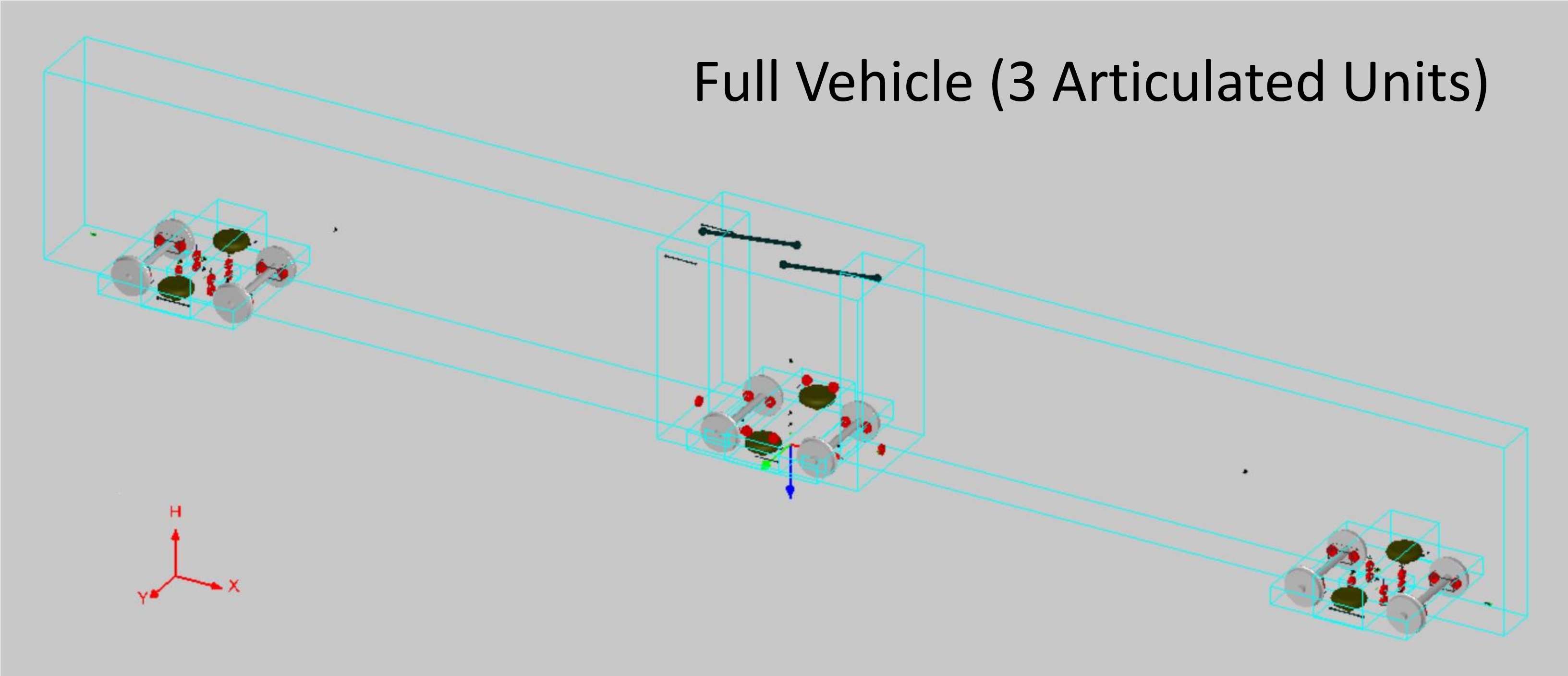
Figure 28: Power truck bolster and kingpin configuration.

Vehicle Model

- Vampire program
- 143 suspension elements connecting masses
- Chevrons, air springs, anchor rods, center bearing, roof dampers, articulating elements etc.



Vehicle Model



Vehicle Model – Wheel Profile

Goals for Wheels

- Reduce hollowing of motor truck wheels
- Reduce flanging
- Reduce tread wear

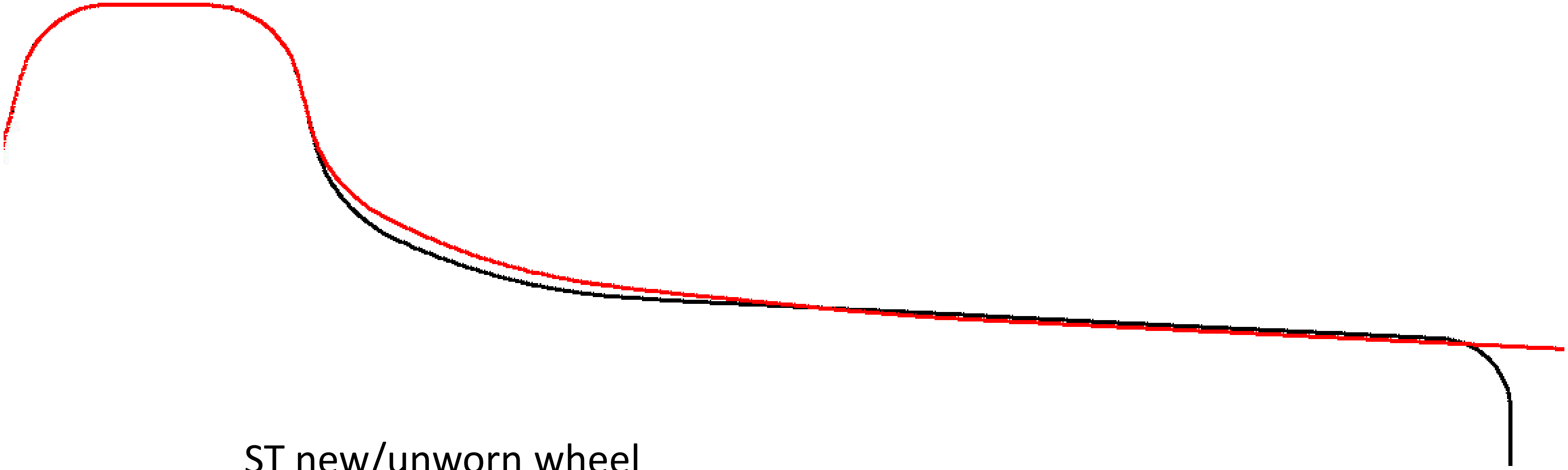
Variables for Evaluation

- Consider different wheel shapes
- Study flange lubrication effect
- Evaluate vehicle mounted friction modifier sticks

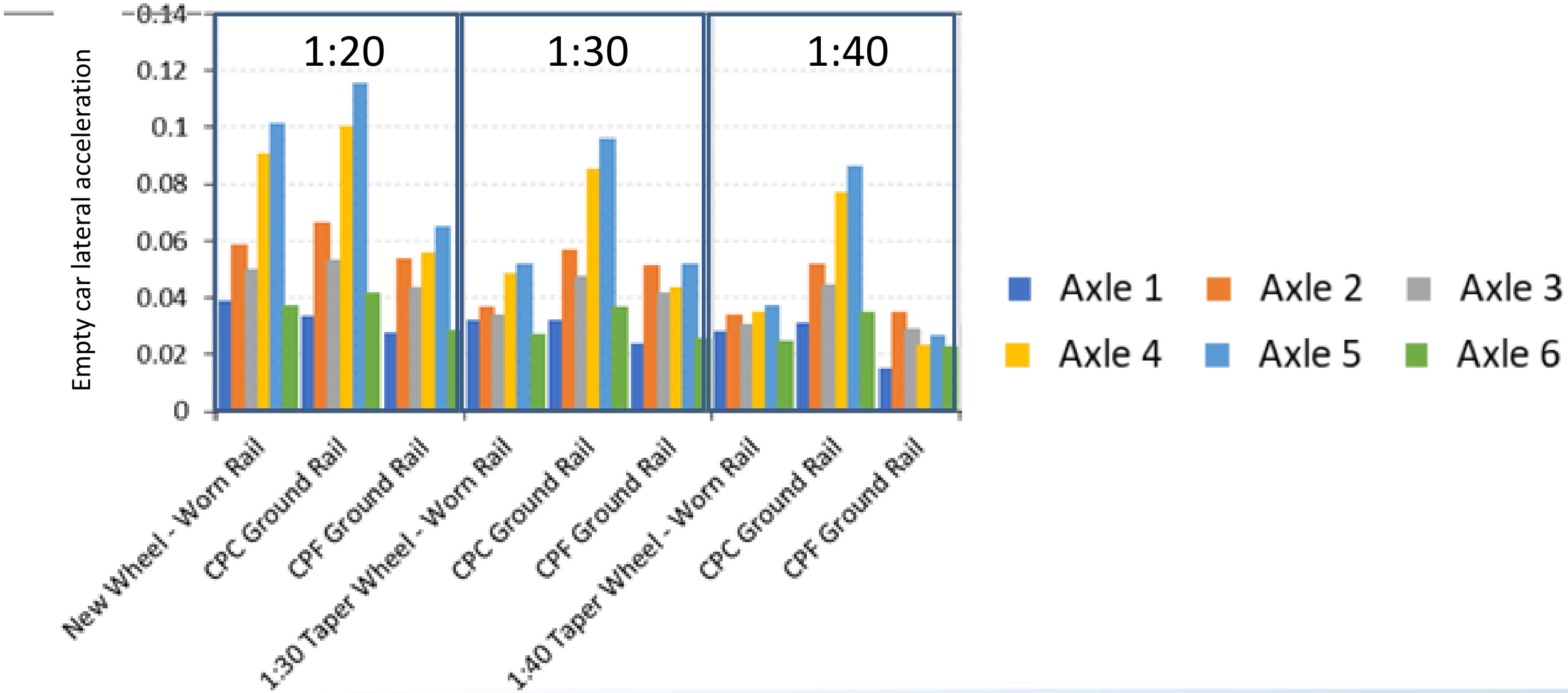
ST's Focus for LRV Performance

- Bogie hunting vs Car hunting
- Damping vs Critical speed
- New wheel vs Worn wheel
- Vehicle-mounted vs Wayside lubrication system
- Pre-overhaul vs Overhauled ST1
- ST1 vs ST2 LRVs

High Conicity Wheel



Rail Profiles & Wheel Taper



Preliminary Observations

- End trucks – High conicity wheels increase hunting and flange wear
- Center trucks – High conicity wheels reduce flange wear in curves but increases tread wear
- Top of rail friction modifiers and flange lubrication reduces wear overall
- A range of wheel tapers can fit current rail shape

Summary

- IRWs pose a challenge for uniform rail and wheel wear in LRV systems at higher speeds
- Sound Transit's rail grinding specification has resulted in significant reduction of train noise and vibration
- Vehicle model & wheel design evaluation is in progress

Questions for Consideration by the North American LRV Industry

- Are IRWs the right approach to design low floor LRVs?
- What modifications need to IRWs are required to improve performance metrics?
- Have transit track design guidelines in North America factored in IRW performance metrics other than safety?