

Using Wheel Rail Interface Analysis to Evaluate Rail Transit Maintenance Priorities:

A Case Study on Los Angeles Metro BLUE Line

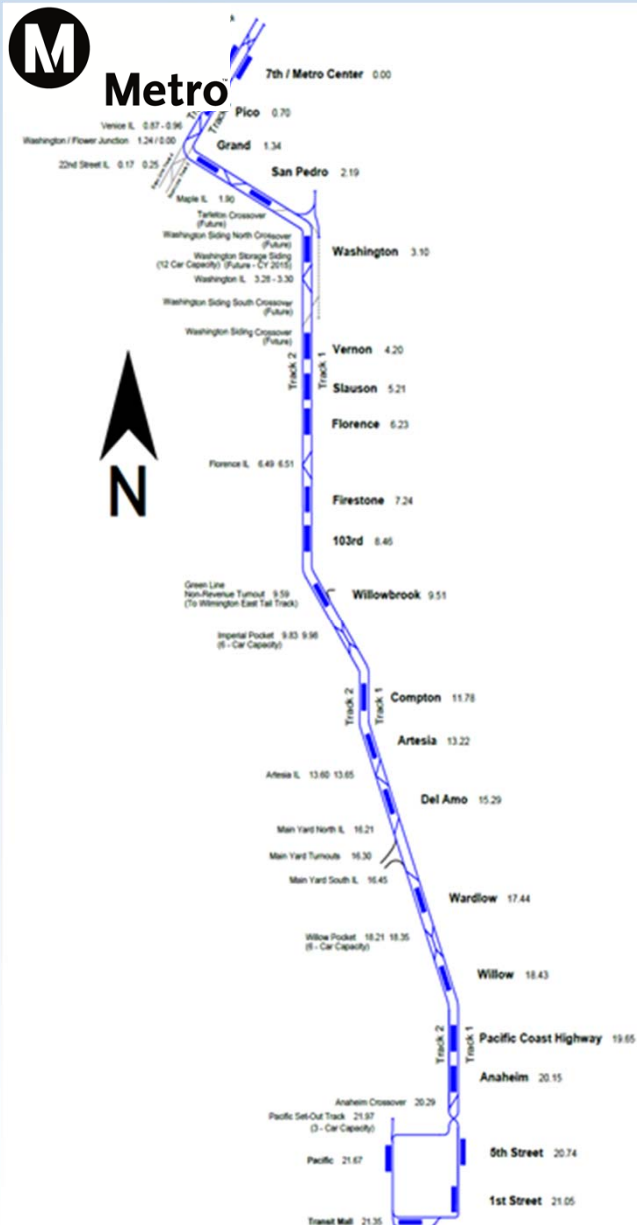


Reasons for Outside Analysis

- New MAP-21 – State of Good Repair Requirements to commence in 2016.
- Metro Blue Line (MBL) basically 25 years old with conditions that may have changed.
- Design Build Modifications to Plant and minor vehicle maintenance issues since the new Expo / MBL Junction had been installed.

An Opportunity for Continuous Improvement

- LA Metro's Pro-Active Approach to improving the up-coming requirements for State-of-Good Repair
- By Using this Pro-Active Approach LA Metro was able to identify conditions before they required Slow Order placement on the system or classified as Major SAFETY ISSUES that would need immediate attention and potential service disruptions



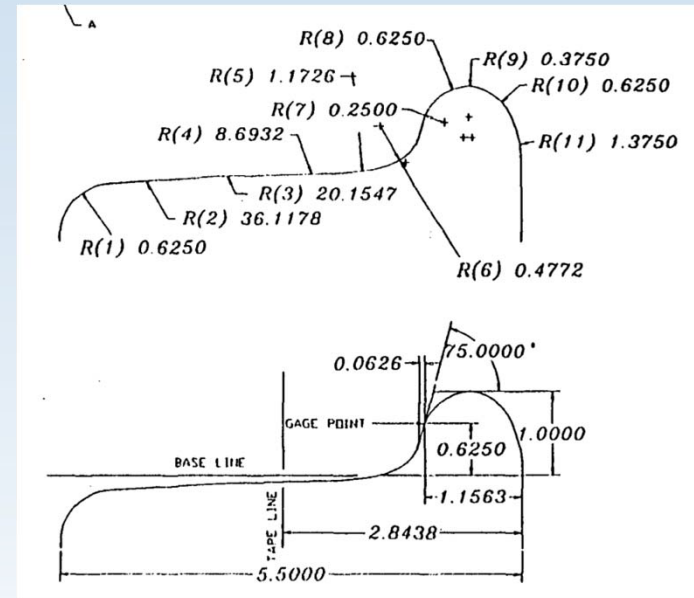
Metro Blue Line History:

- ❖ 14 July 1990: Metro Blue Line Opened
- ❖ 30 Jan 1993: Union Station-
Westlake/MacArthur Park
- ❖ 12 Aug 1995: Metro Green Line Opened
- ❖ 13 July 1996: Westlake/McArthur Park –
Wilshire/Western
- ❖ 12 June 1999: Wilshire/Vermont –
Hollywood/Highland
- ❖ 24 June 2000: Hollywood/Highland – North
Hollywood
- ❖ 26 July 2003: Metro Gold Line Union Station –
Sierra Madre Villa
- ❖ 15 Nov 2009: Metro Gold Line Union Station –
Atlantic
- ❖ 28 Apr 2012: Metro Expo Line 7th Street/
Metro Center – La Cienega/Jefferson
- ❖ 20 June 2012: Metro Expo Line
La Cienega/Jefferson–Culver City + Farmdale



Current LA Metro Improvements

- Changed standard AAR Wheel and Rail to Custom Metro Rail Wheel Profiles and Custom Grinding of Rail to improve Wheel Life – Mid 1990's.



- ✖ Expo Line to Expand from Culver City to a new three - track terminal at 4th Street in Downtown Santa Monica – 2016.
- ✖ Gold Line to Expand from Sierra Madre Villa to City of Azusa – 2016.



LA Metro Blue Line Program for Maintenance Prioritization



Background

- LA Metro requested Advanced Rail Management (ARM) to perform a dynamic assessment of its Blue Line
- Primary focus given to special trackwork to determine major contributors to track and rail car dynamics and damage

Methodology

- Take a Systems approach to evaluate track behavior based on vehicle response driven by wheel/rail interaction (WRI)
 - Collect data of representative vehicles over the entire Metro Blue Line
 - Develop acceptable performance levels for special trackwork
 - Determine special trackwork that exceed acceptable performance levels

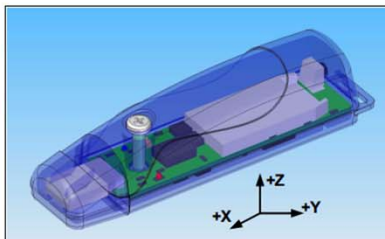
Testing on Metro Blue Line

- Testing was performed over the entire blue line system
- Both car types tested
- Testing was conducted at track speeds over the entire route

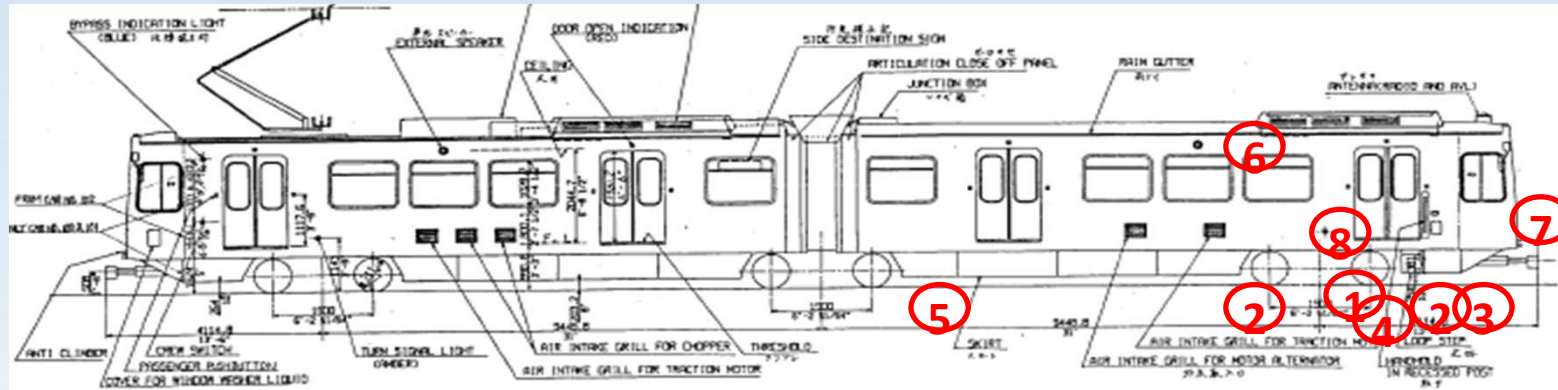
Instrumentation

- Each car was instrumented with a calibrated set of accelerometers, a string potentiometer (string pot), video of wheel/rail interface, video from car cab, an under car microphone, and GPS

Parameter	X500-2			X250-2			X50-2		
	Min	Typ	Max	Min	Typ	Max	Min	Typ	Max
Acceleration range		±500			±250			±50	
Resolution		0.0916			0.0381			0.0080	
Linearity		±0.2	±2.0		±0.2	±2.0		±0.2	±2
-3dB Frequency	32K	32K	32K	360	400	440	360	400	44



Instrumentation Placement Car Perspective



- (1) Truck mounted tri-axial accelerometer
- (2) Truck mounted video camera
- (3) Under car audio
- (4) String Potentiometer to measure rotation
- (5) Car mounted video cam of the center truck
- (6) GPS
- (7) Cab Camera
- (8) Carbody Accelerometer

Camera Layout View

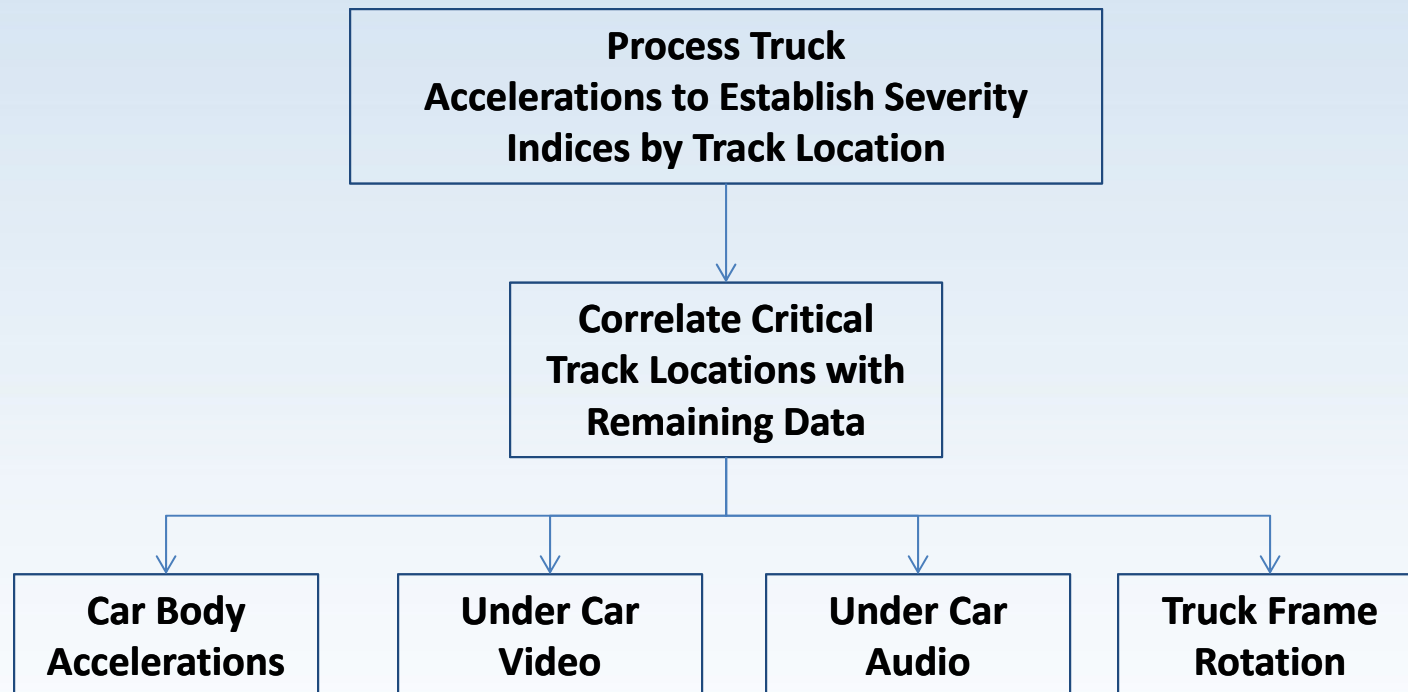


Frame	View
1	Axle 1 Rgt
2	Axle 1 Lft
3	Axle 2 Lft
4	Axle 2 Rgt
5	Cab View
6	Center Truck
7	Speed, mph

CAMERA ORIENTATION NOTES

- Axle 1 is the end axle, Cameras are oriented toward Center of Car
- Axle 2 is the inboard axle, Cameras are oriented toward End of Car
- Center Truck, Camera is oriented toward the Center of the Car

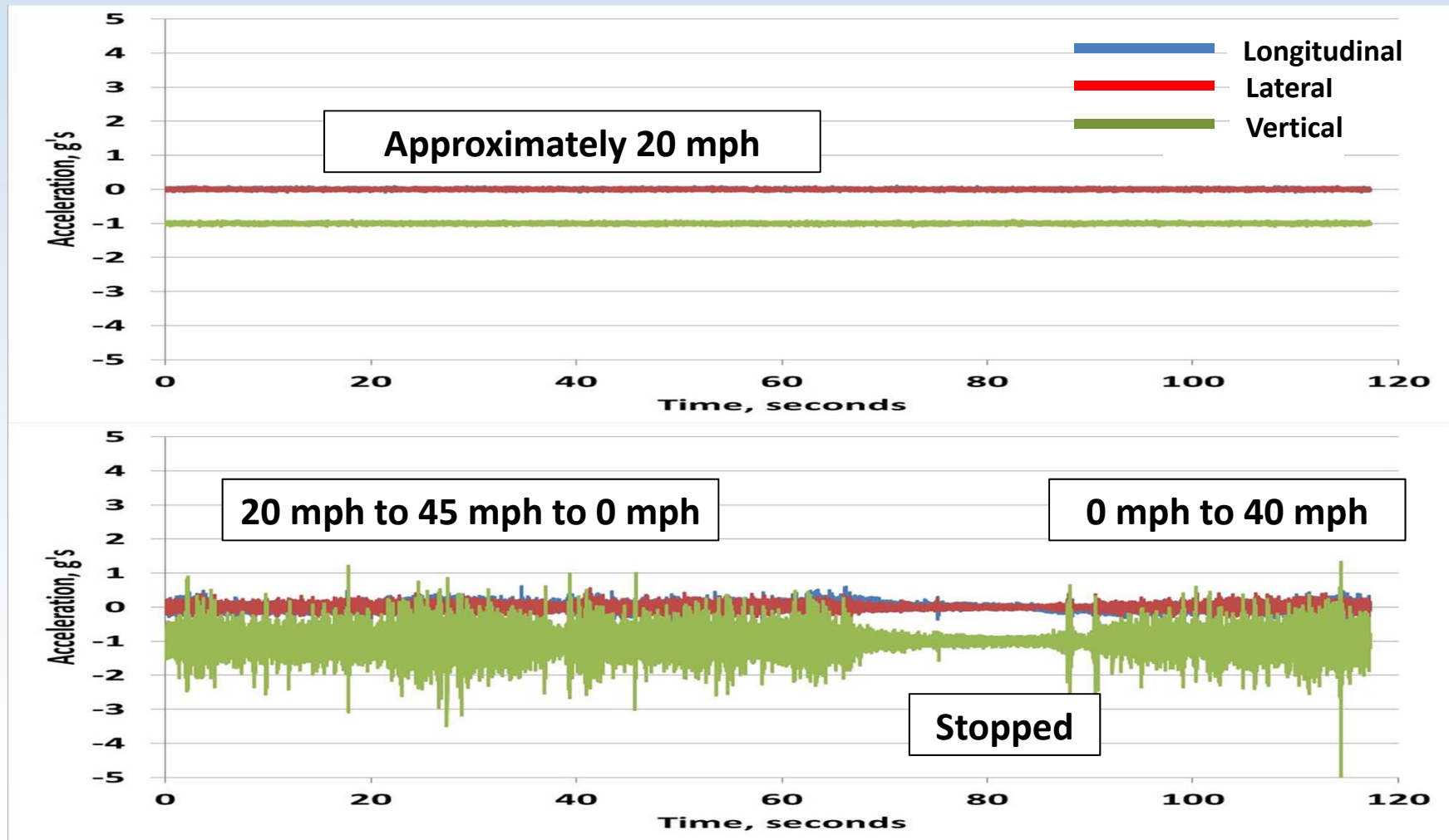
Data Processing



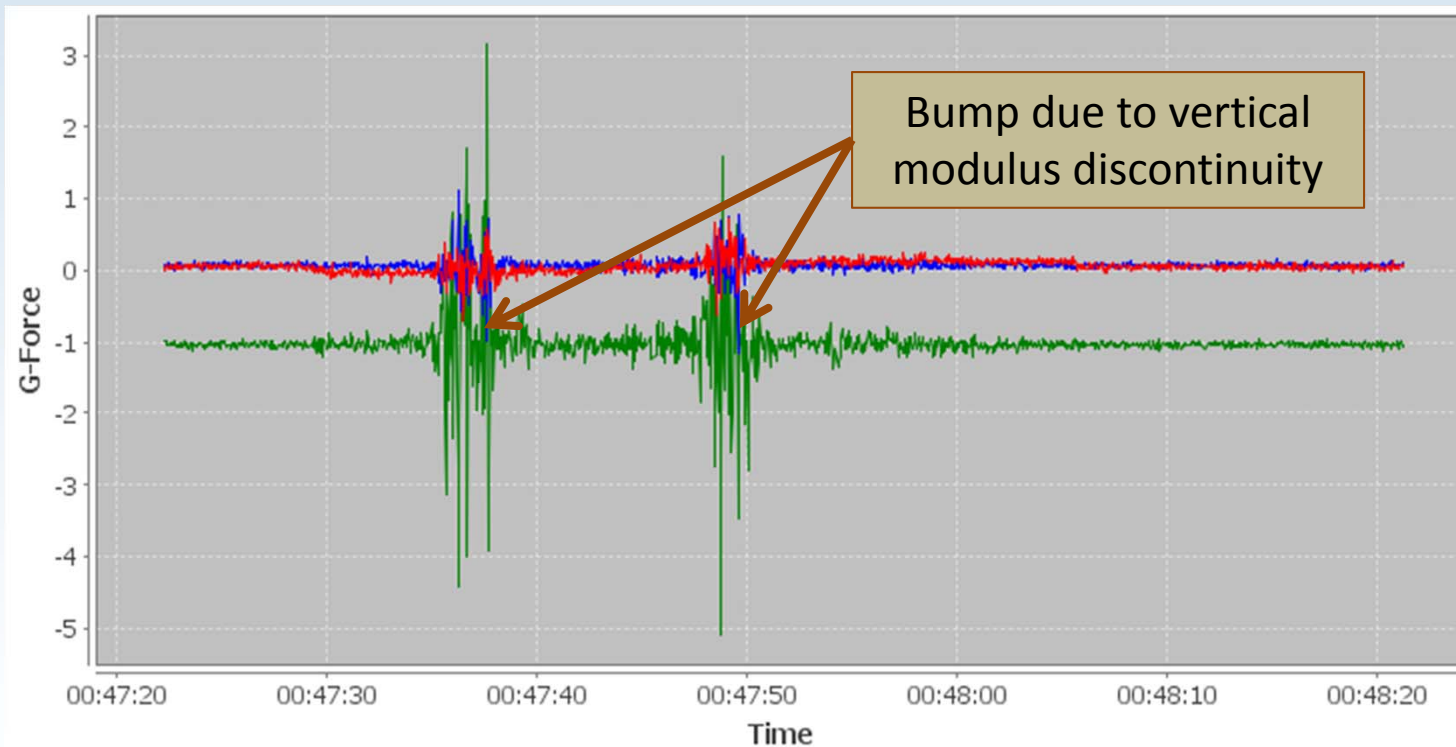
Fundamentals of Data Processing Assumptions

- Data is processed by a relative energy method based on RMS
- RMS allows for easy determination of events that disturb steady-state behavior
- Things that effect the steady-state:
 1. Train Handling: Acceleration/Deceleration
(Disregarded)
 2. Perturbed Tracks: Modulus Changes, Severe Corrugations, etc. *(What we are looking for)*

Errors Induced by Train Handling



Errors Induced by Track Events



Data Processing

Truck Acceleration Analysis

- Perform RMS-based analysis of the composite truck frame acceleration

- Compute Severity Index for Track Feature

$$\text{—} \quad \text{SI} = \frac{[\text{RMS Related Value for Track Feature}]}{[\text{RMS Related Value for Tangent Track}]}$$

Tracking Bias and Hunting

- Both the P-865 and P-2000 were found to have an offset or Tracking Bias. The wheels on one side of each test car ran closer to the rail in tangent track than the wheels on the opposite side
- The P-2000 was found to experience hunting onset at 45 mph and sustained hunting at 50 mph and up

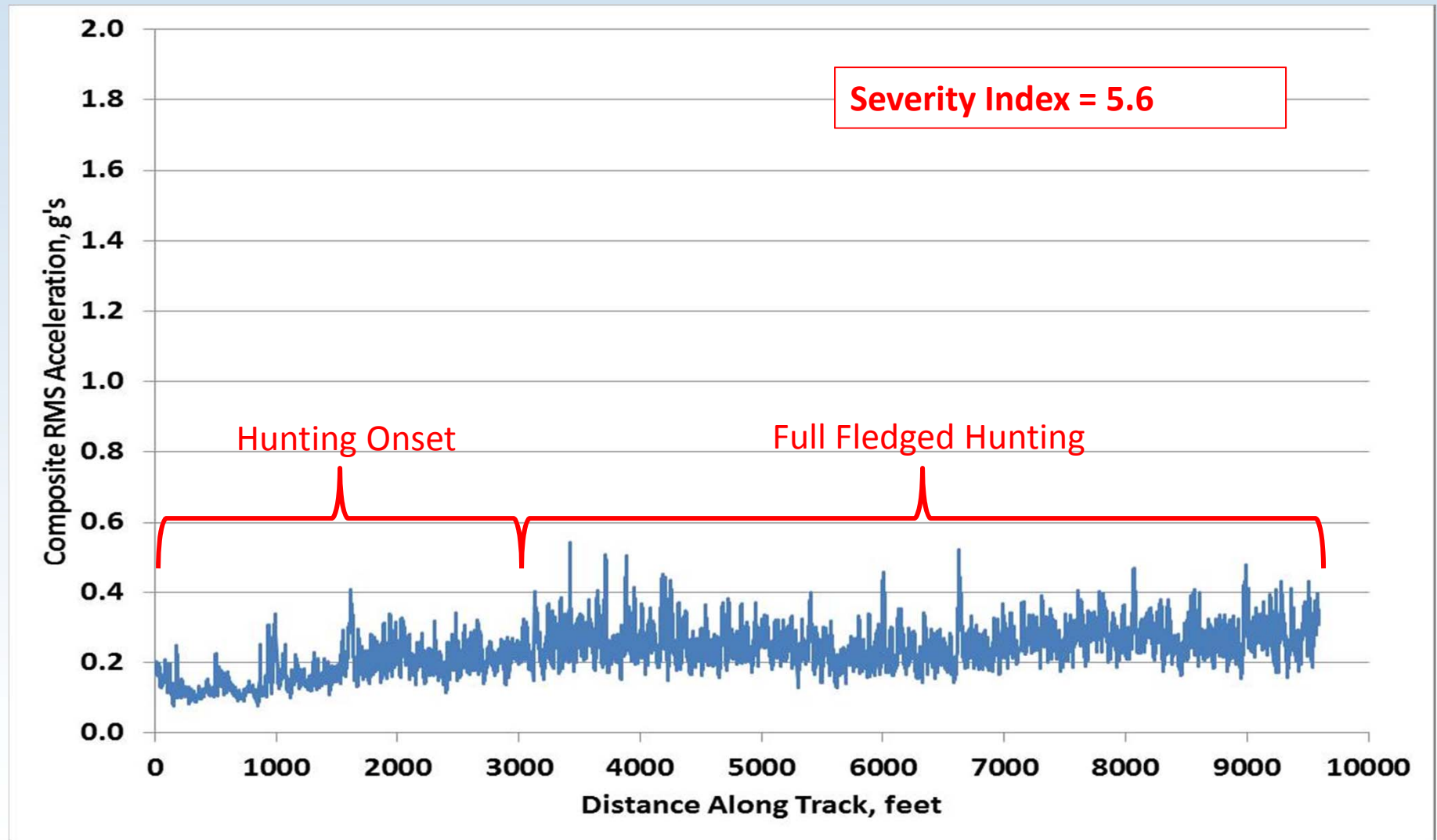
P-865 Tracking Bias



P-2000 Tracking Bias



P-2000 Hunting



P-2000 Hunting





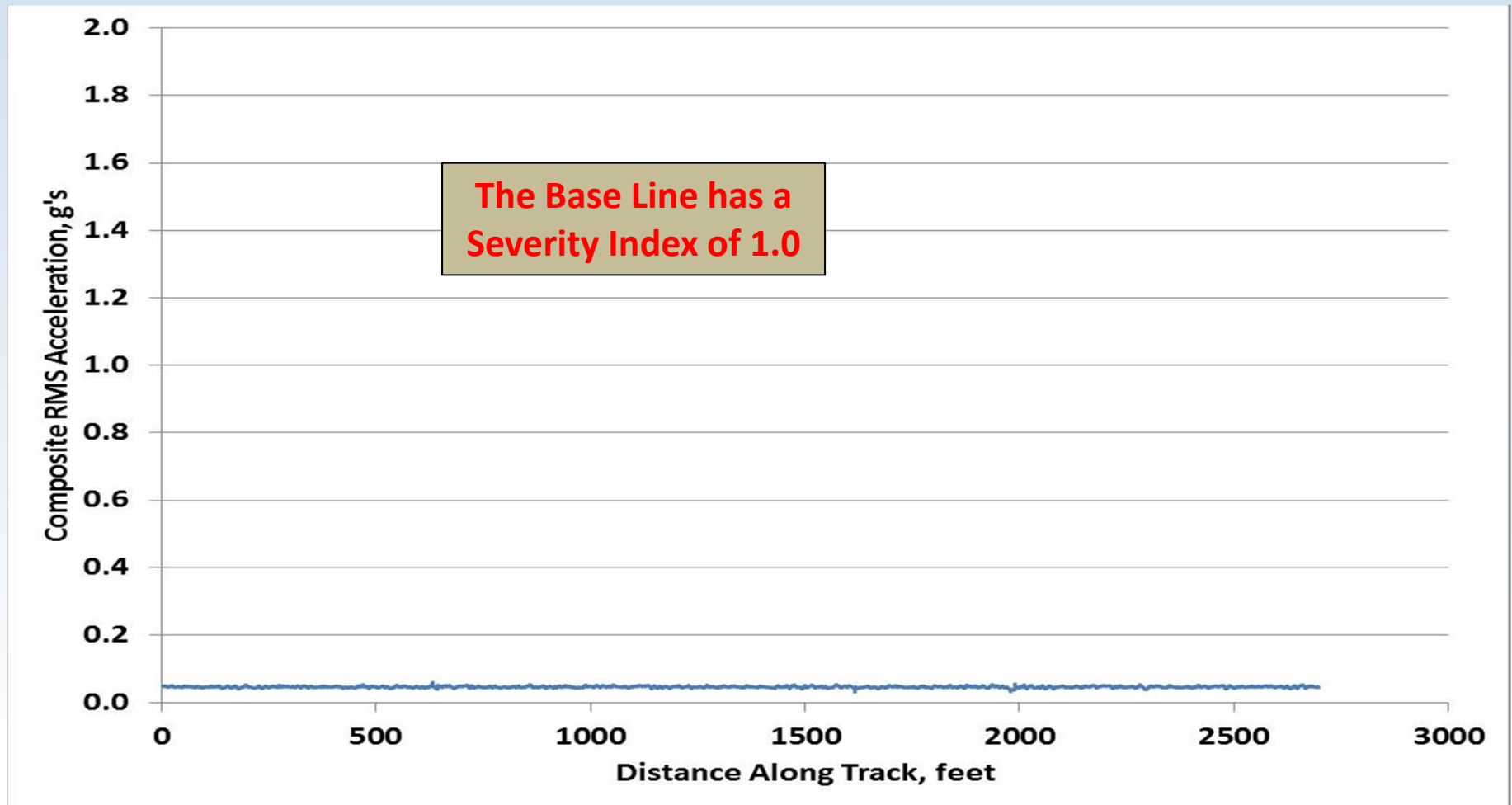
Dynamic Review

Special Trackwork



Baseline

33 MPH Run with P-865 Car



Typical P-865 Run

Acceptable Performance Levels

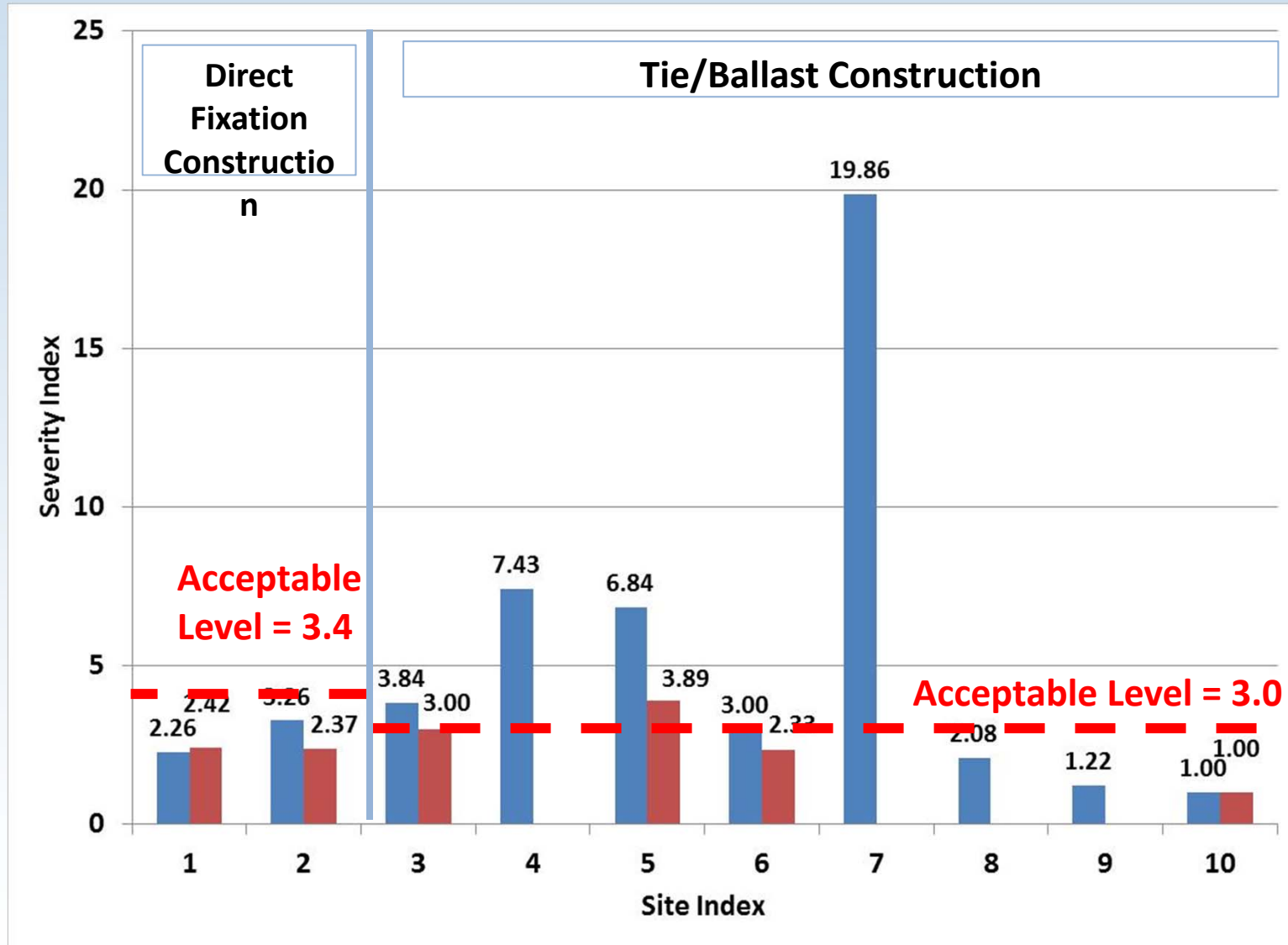
- Two basic types of track construction on the Blue Line
 1. Direct Fixation
 2. Tie/Ballast



Acceptable Performance Levels

Direct Fixation	Tie/Ballast
3.4	3.0

Statistical techniques were applied to determine a range of “normal” Severity Indices for special trackwork of each track type. The upper end of each range define the Acceptable Performance Levels



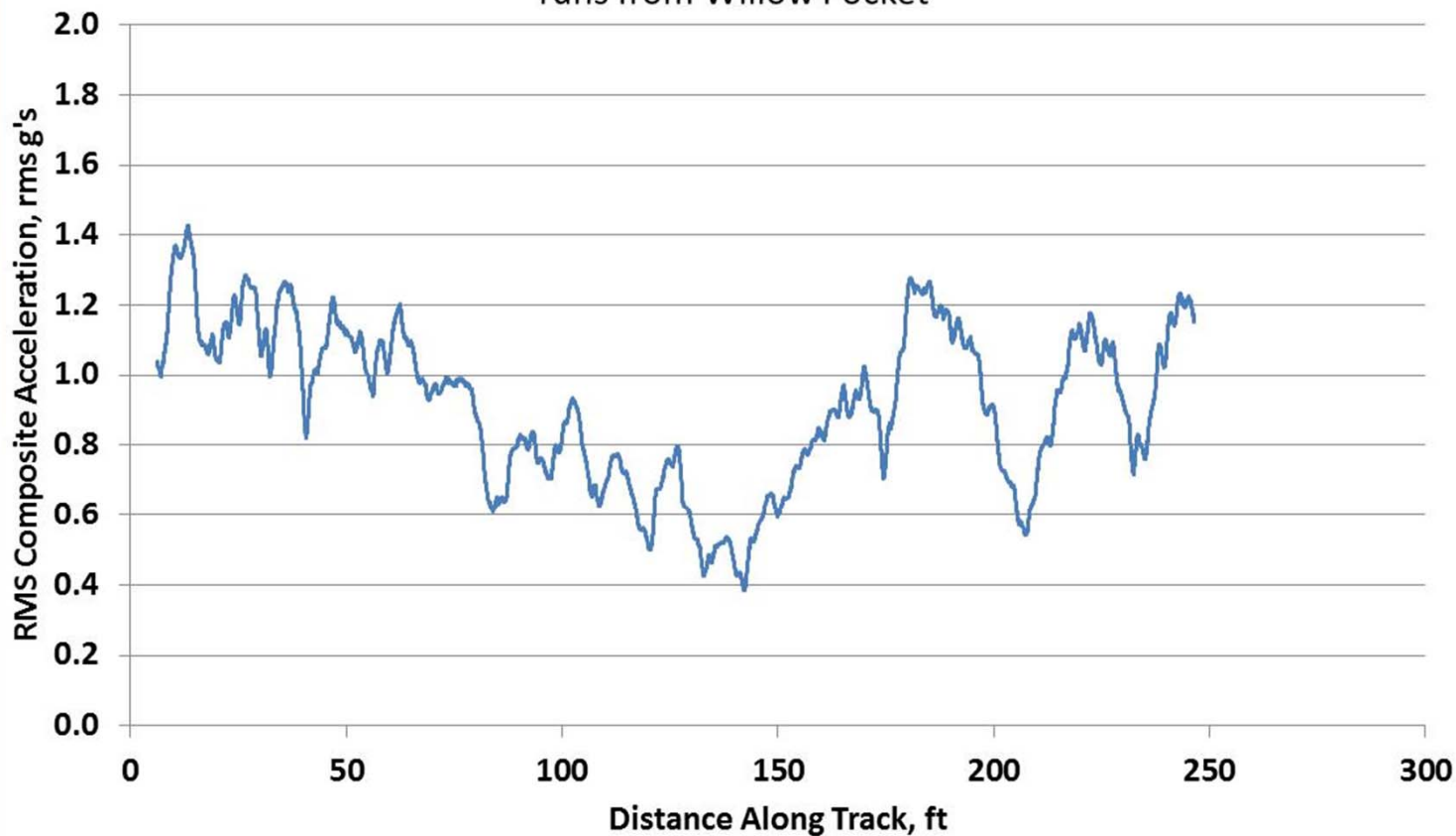
Metro Site 7

- The #10 Crossovers & Turnout North-Bound into Division 11 Yard from Trk #1 to Trk #2 and into the Yard from LA River Bridge into the Yard on our end of test runs from Willow Pocket
- Severity Index of **18.96** (P-865)
- This area was noted by LA Metro as having rotten ties and in the process of tie replacement



Site 7

The #10 Crossovers North-Bound into Division 11 Yard from Trk #1 to Trk #2 and into the Yard from LA River Bridge into the Yard on our end of test runs from Willow Pocket



P-865 Car

Metro Site 7 Video

P-865 Car



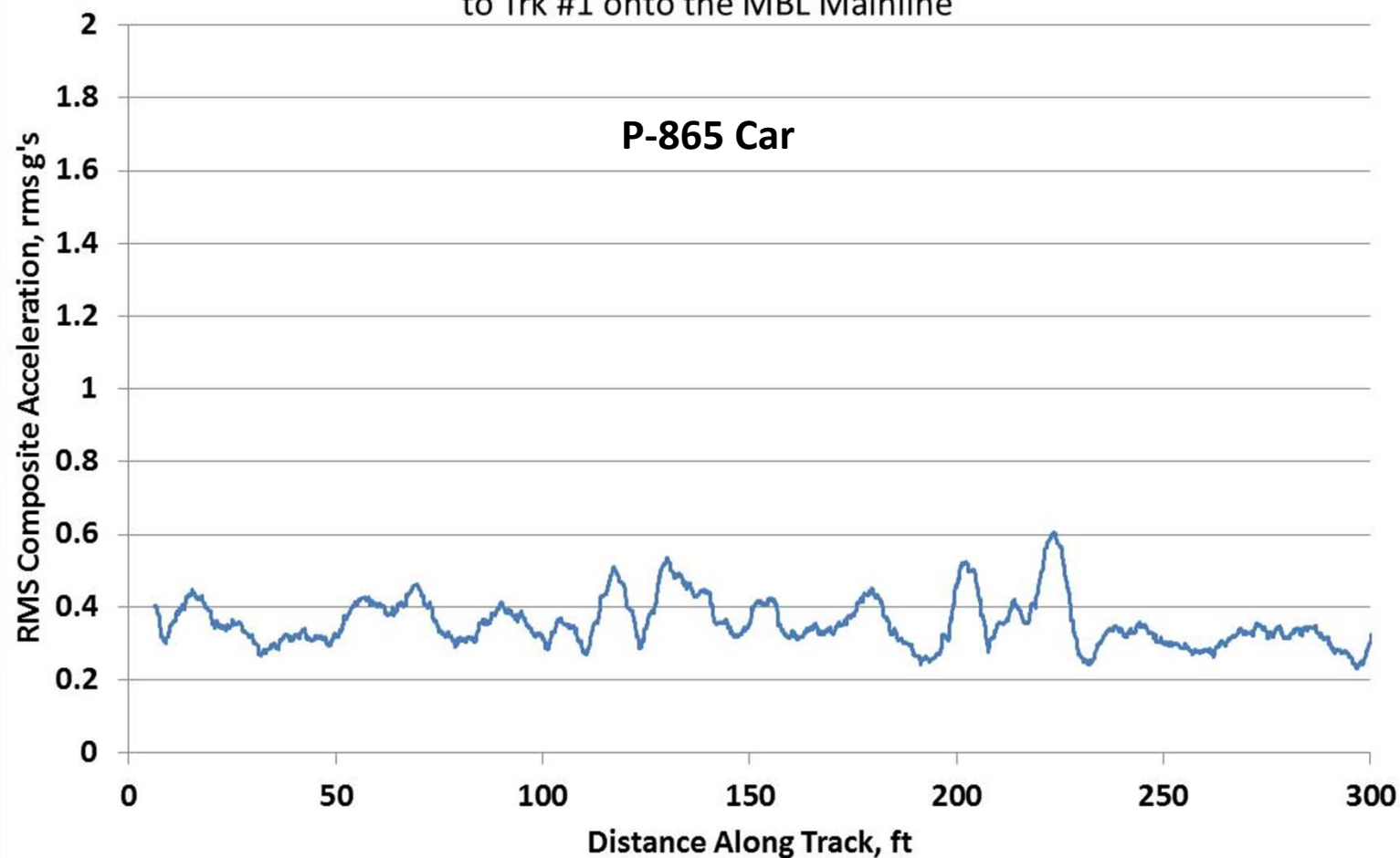
Metro Site 4

- The #10 Turnout & Crossovers North-Bound out of the Division 11 Yard from Yard to Trk #2 to Trk #1 onto the MBL Mainline
- Severity Index of **7.43** (P-865)
- Site of wood tie/ballast construction with poor drainage



Site 4

The #10 Crossovers North-Bound out of the Division 11 Yard from Trk #2 to Trk #1 onto the MBL Mainline



Metro Site 4

P-865 Car



Metro Site 5

- The 190' R Turnout and 160' R Diamond at the Expo / MBL Junction just north Washington Blvd on Flower Street
- Severity Index of **6.84** (P-865) & **3.89** (P-2000)
- Construction of wood tie/ballast with alignment design issues and crossing frog modification



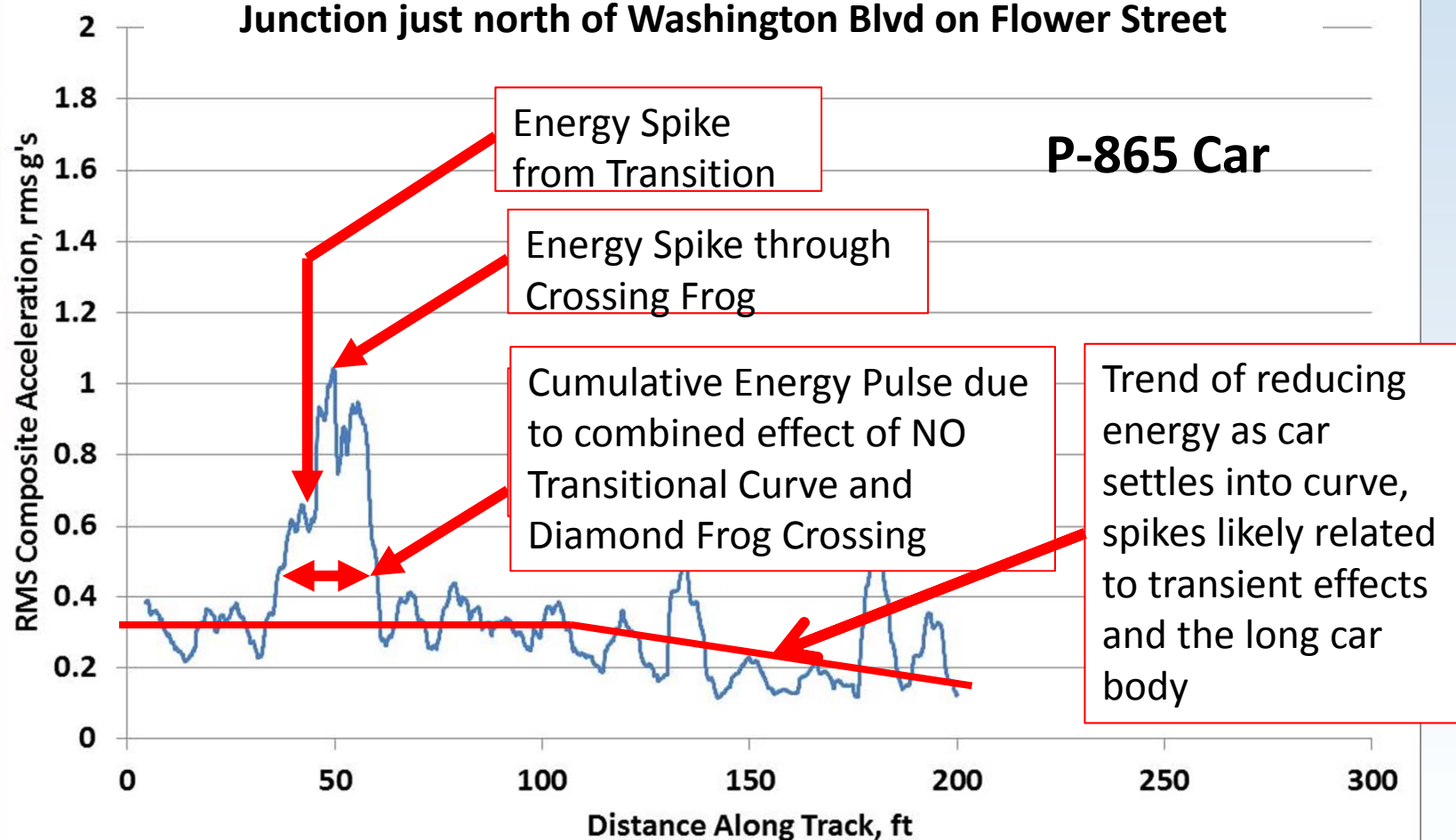


Metro



Site 5

The 190' R Turnout and 160' R Diamond at the Expo/MBL Junction just north of Washington Blvd on Flower Street



Metro Site 5

P-865 Car



Conclusions

1. With minimal basic instrumentation, critical maintenance areas for LA Metro were determined and prioritized
2. The Severity Index developed proved a useful and accurate tool in assessing track issues
3. Use of the under car video was able to identify and verify performance not only in predetermined track features, but also in unexpected areas during system runs

Summary

- ❖ This refined WRI Analysis can be used before normal Inspections or before Standard Safety Critical Issues are identified creating panic and service disruption, and allow the agency to better prepare for maintaining a State of Good Repair as a Pro-Active Approach