Treatments at the Wheel/Rail Interface to Reduce Rail Transit Noise

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TRB ADC40
asheville 2012

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Tools for Reducing Wheel/Rail

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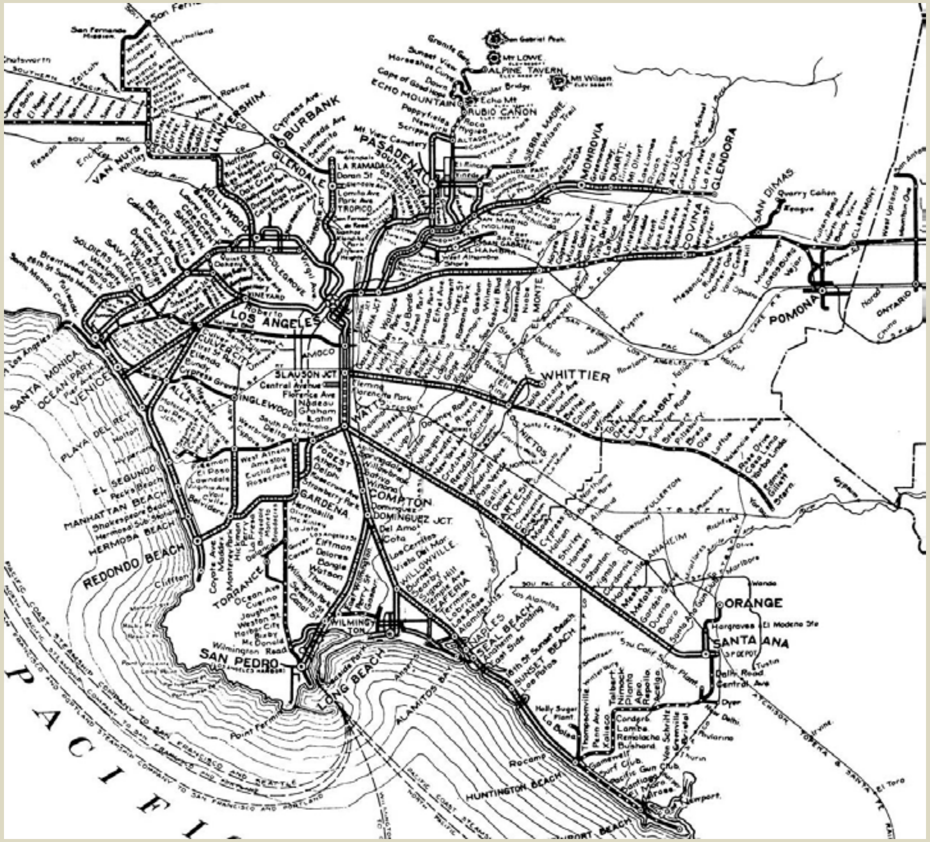
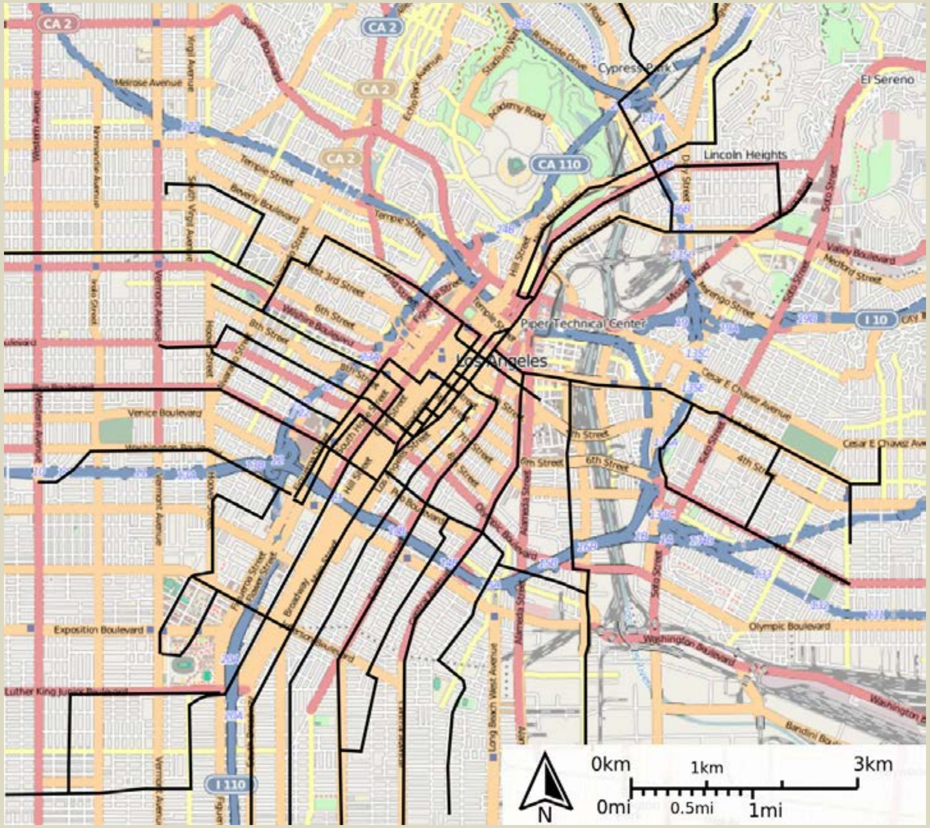
Los Angeles Rail Transit in 1930's





Current Transit Projects in LA County

Project	Cost	Type	Status
Metro Orange Line Extension	$182M	BRT	Under construction
Crenshaw/LAX Transit Corridor	$1.21B	LRT	Design Build RFP stage
Regional Connector Transit Corridor	$1.4B	LRT	Design Build RFP stage
Exposition LRT Project Phase 1	--	LRT	Opened in May 2012
Exposition LRT Project Phase 2	$925M	LRT	Under construction
Gold Line Foothill Extension Ph. 1	$735M	LRT	Under construction
Gold Line Foothill Extension Ph. 2	--	LRT	Environmental review
Eastside Transit Corridor Phase 2	$1.27B	LRT	Environmental review
Green Line Extension to LAX	$200M	LRT	Alternatives Analysis
Sepulveda Pass Transit Corridor	$1.08B	RT	Initial Planning
South Bay Green Line Extension	$272M	LRT	Environmental review
West Santa Ana Transit Corridor	$240M	Undef	Alternatives Analysis
Westside Subway Extension	$4.07B	RT	Preliminary Engineering

Modern Urban Rail Transit Systems*

Western North America	
City/Region	**Type**
Calgary	Light rail
Denver	Light rail
Edmonton	Light rail
Honolulu	Rapid transit
Los Angeles	Rapid transit and LRT
Phoenix	Light rail
Portland, OR	Light rail
Sacramento	Light rail
Salt Lake City	Light rail
San Diego	Light rail
San Jose	Light rail
Seattle	Light rail
SF Bay Area	Rapid transit and LRT
Vancouver	Light rail

Eastern North America	
City/Region	**Type**
Atlanta	Rapid transit
Baltimore	Rapid transit and LRT
Buffalo	Light rail
Charlotte	Light rail
Dallas	Light rail
Houston	Light rail
New Jersey,	Light rail
Miami	Rapid transit
Minneapolis	Light rail
Norfolk, VA	Light rail
St. Louis	Light rail
San Juan	Rapid transit
Toronto	Rapid transit and LRT
Wash., DC	Rapid transit

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List is not exhaustive and does not include commuter rail or streetcars!

Clearly noise is an issue for both new and existing systems

Questions are:

- What can be done other than put up sound walls?
- As systems age, will noise increase?
- What tools are available to reduce noise at the wheel/rail interface?
  - Monitoring track and wheel condition
  - Improved maintenance procedures
  - Wheel and track treatments (e.g. tuned vibration dampers)
- How big a difference will treatments make?

Definitions

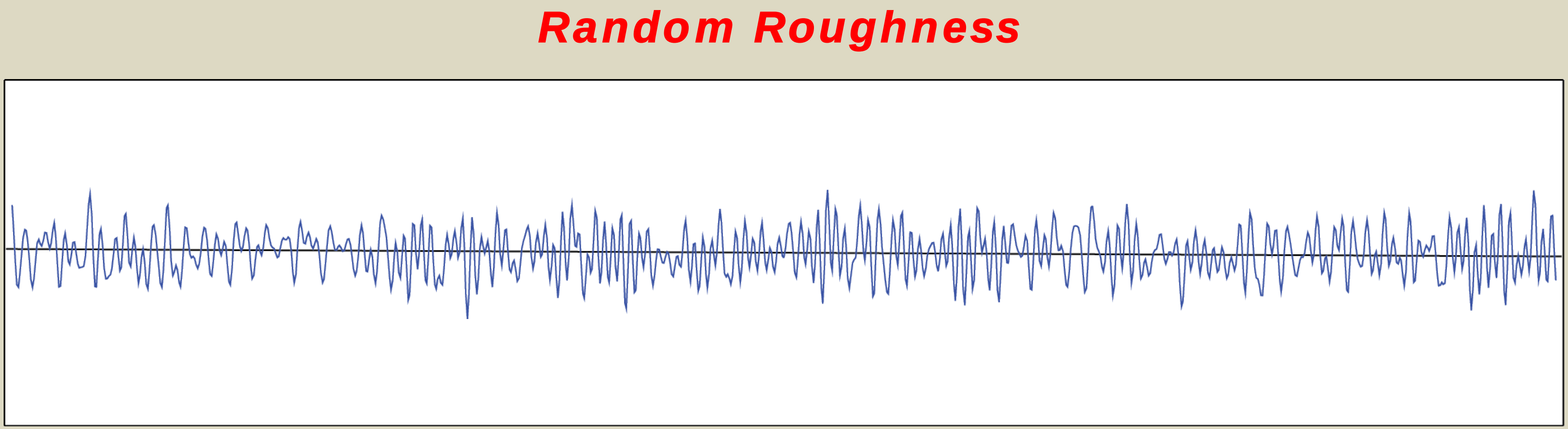
- Potential wheel/rail noise sources
  - Rolling noise
  - Squeal from slip-stick interaction on rail head, flange/gauge face contact, restraining rail or guard rail contact
  - Impacts at frogs, joints, bad welds, wheel flats
- Roughness
  - Random roughness plus periodic roughness (corrugation)
  - Mathematical models assume:

$$SPL = \ldots + 10\log\left[\left(\frac{\rho c \omega}{p_0}\right) H_{cp}(k)\varphi_{mR}(k)\Delta k\right]$$

where φmR(k) is the combined wheel and rail roughness (Remington, et. al., 1974).

"Roughness"

Any longitudinal irregularity in rail surface

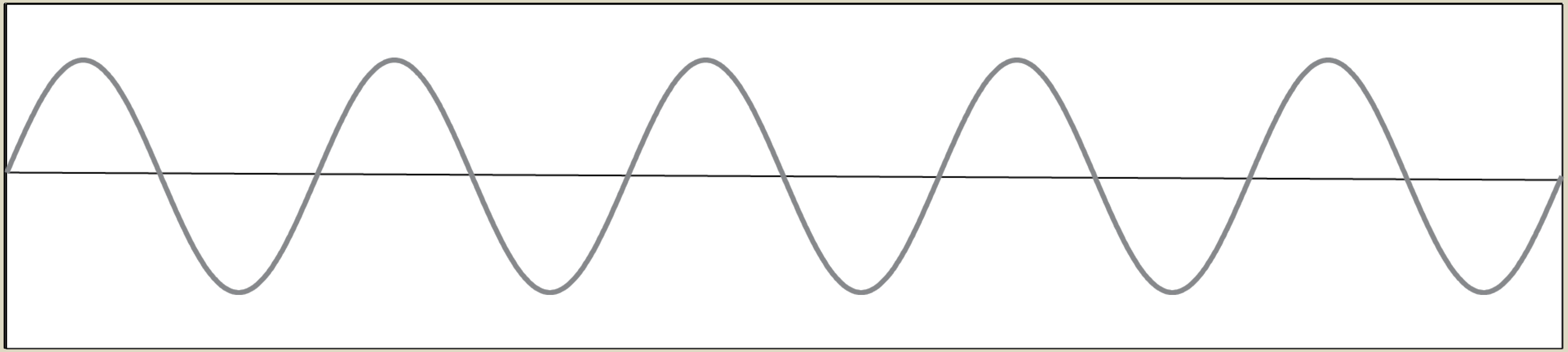


$$frequency = speed / wavelength$$
$$= 17.9 \times speed(mph) / wavelength(inches)$$
$$= 447 \times speed(mph) / wavelength(mm)$$

“Roughness”

Any longitudinal irregularity in rail surface

Corrugation



$$
\begin{aligned}
frequency &= speed / wavelength \\
&= 17.9 \times speed(mph) / wavelength(inches) \\
&= 447 \times speed(mph) / wavelength(mm)
\end{aligned}
$$

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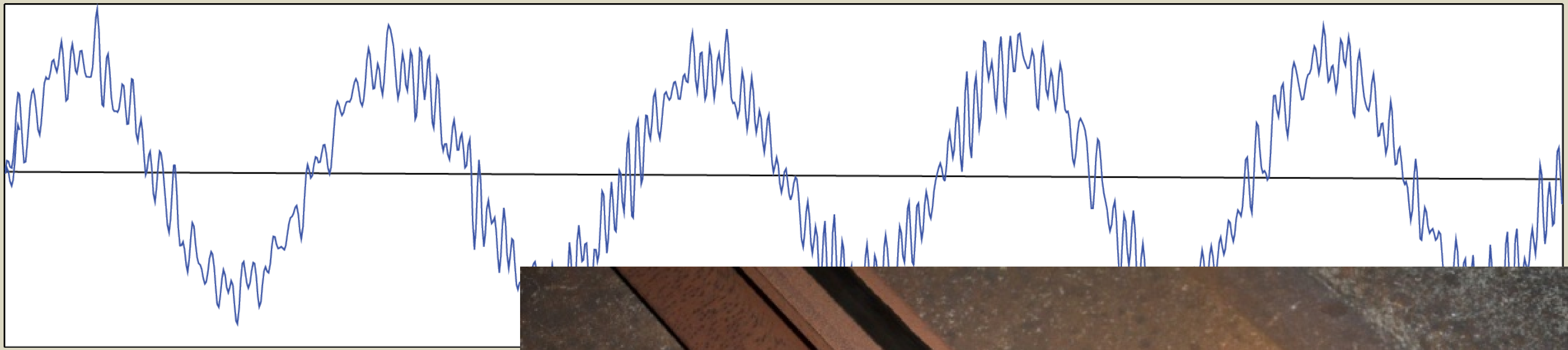
"Roughness"

Any longitudinal irregularity in rail surface

Combined Corrugation and Random



$$\begin{aligned} frequency &= speed / wavelength \\ &= 17.9 \times speed(mph) / wavelength(inches) \\ &= 447 \times speed(mph) / wavelength(mm) \end{aligned}$$

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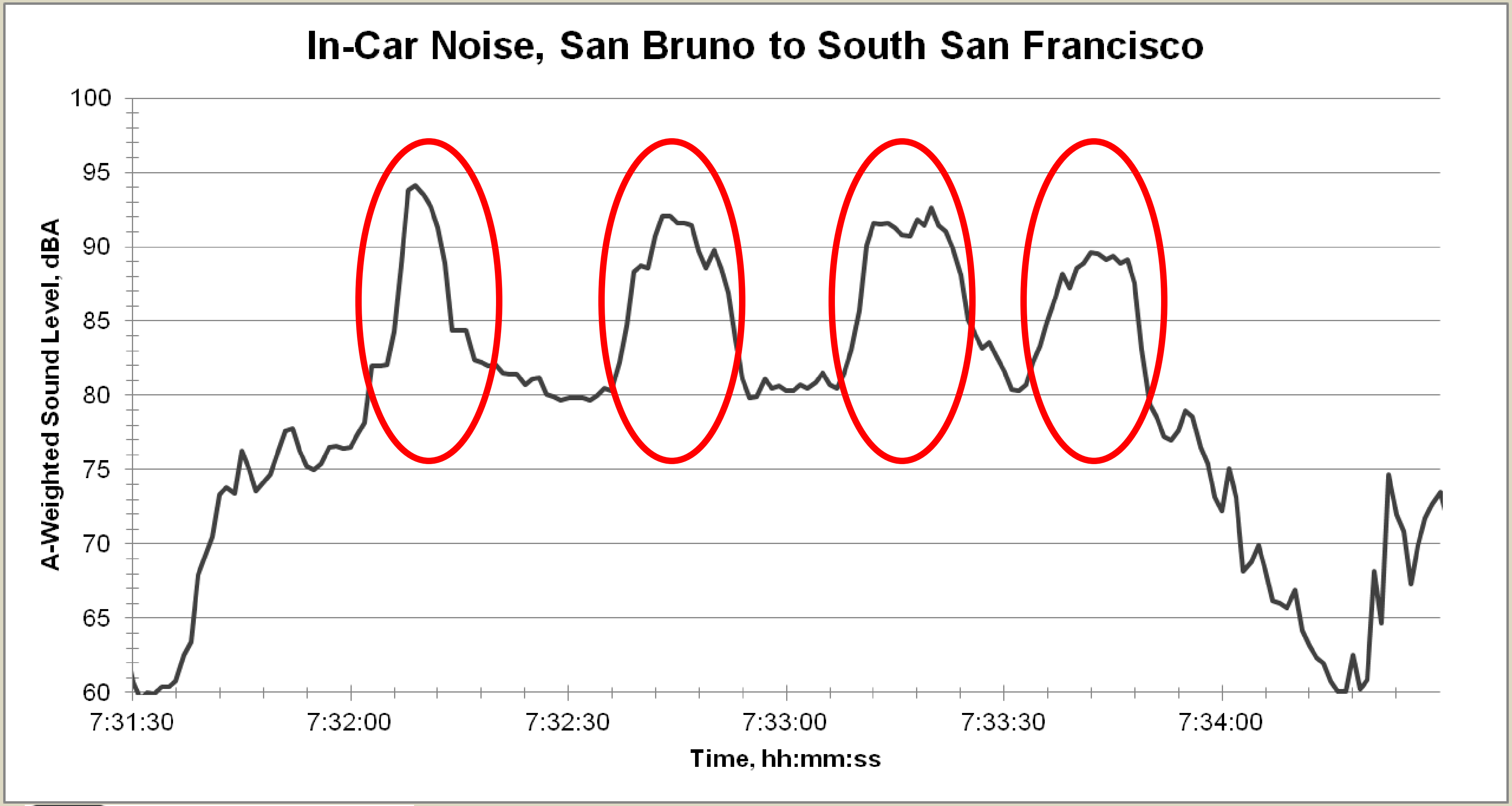
Tools for Evaluating Noise

- On-board noise measurements to identify problem areas
- Detailed measurements at selected sites
  - Community noise
  - Rail roughness
  - Noise at 1m from near rail
  - Rail vibration decay rate
  - Rail Input Impedance
- Wheel input impedance

On-Board Noise Measurements

On-Board Noise Measurement, 2003



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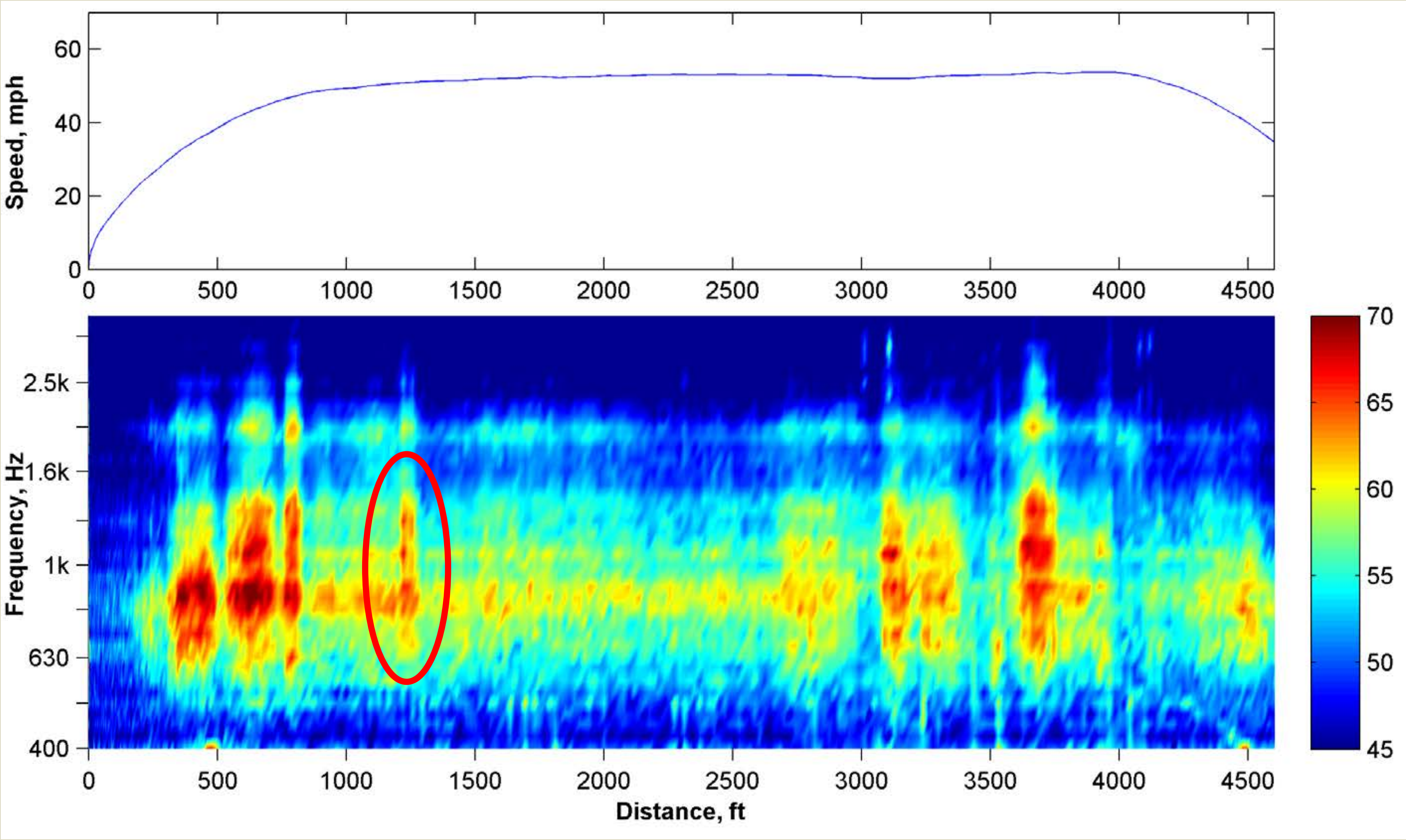
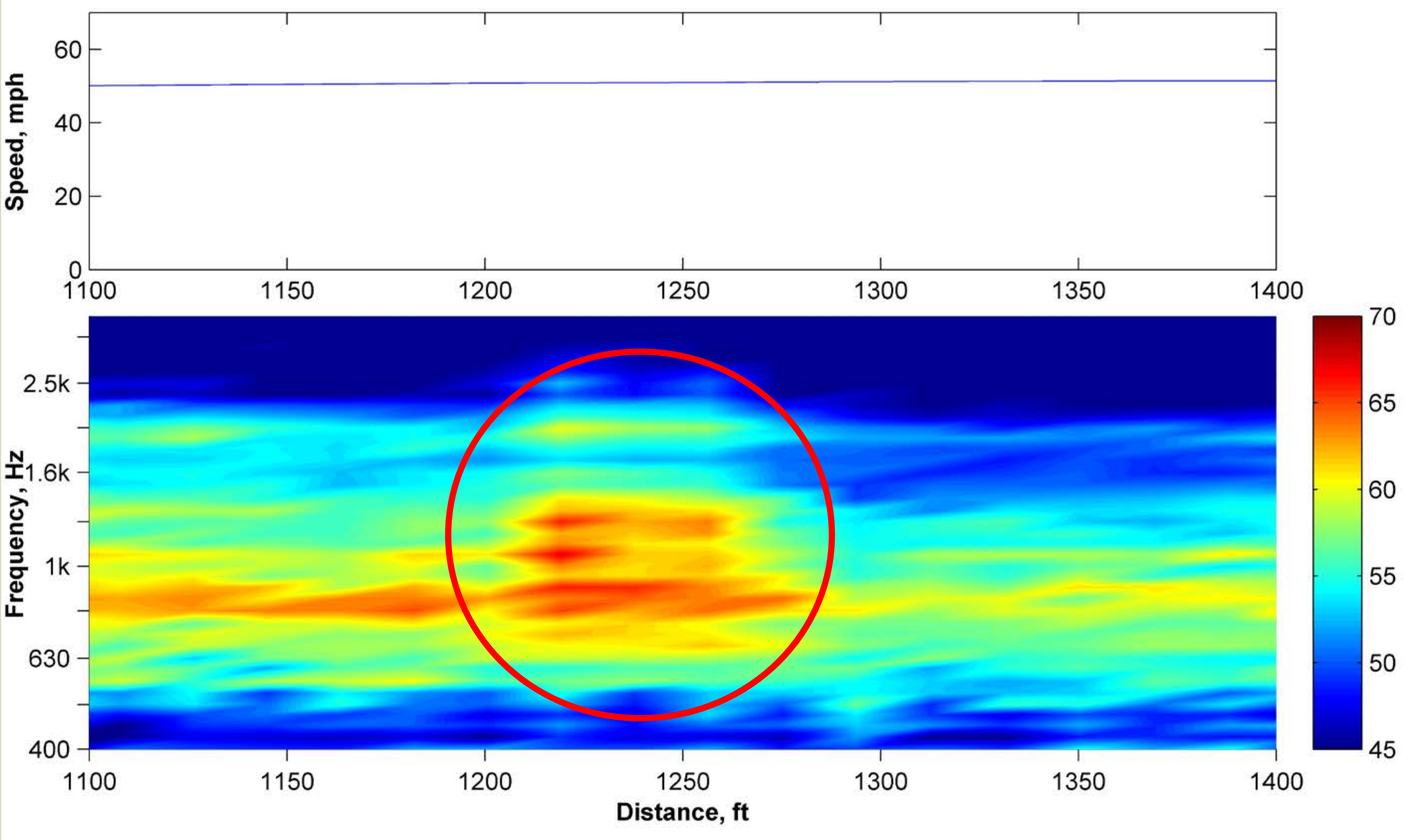
On-board Noise Measurement

Station to Station



Area of Interest



“Corrugation” from Rail Grinding

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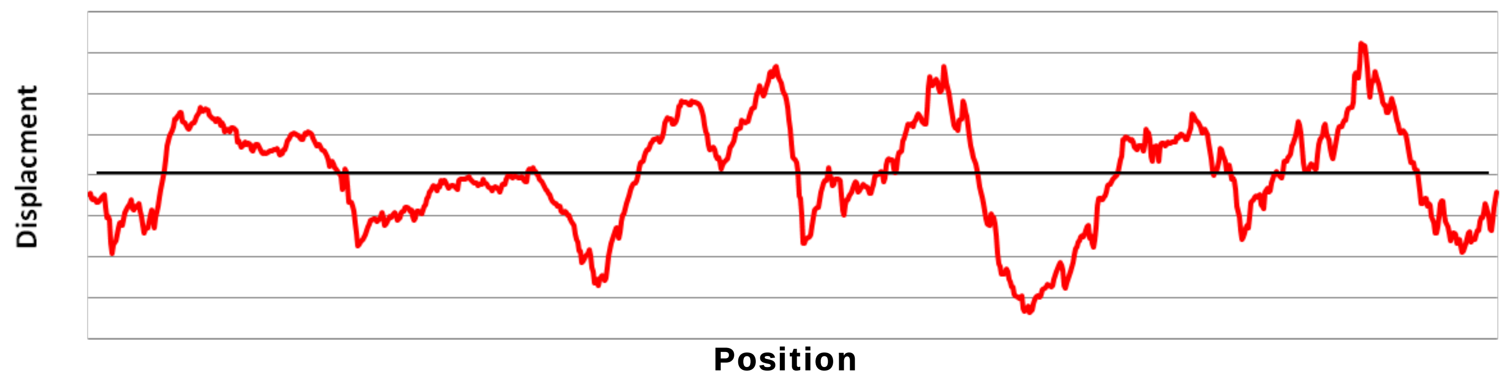
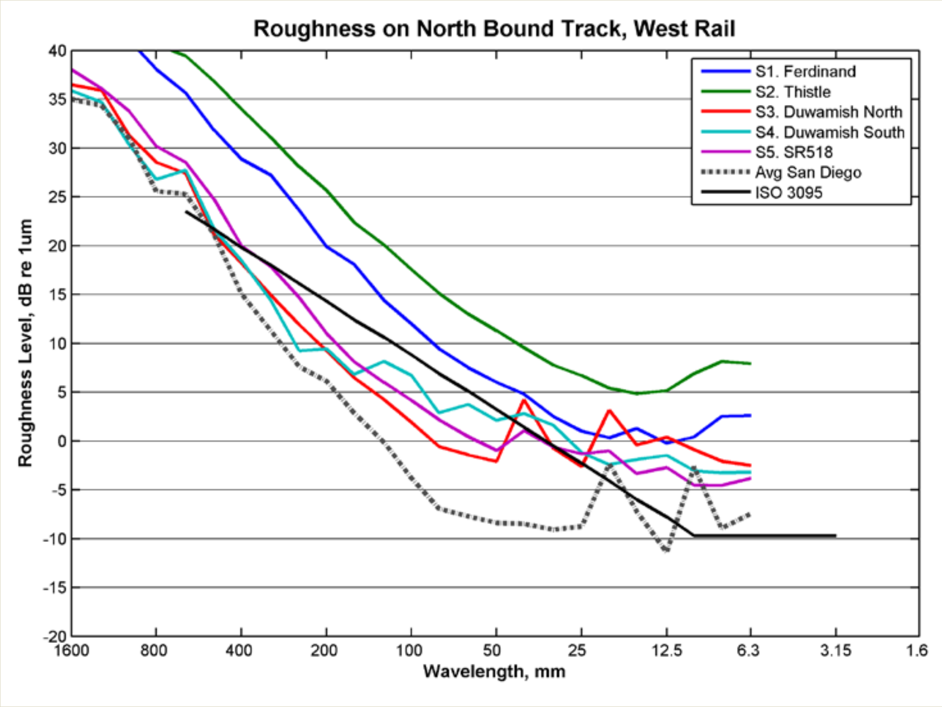
Rail Roughness Measurements

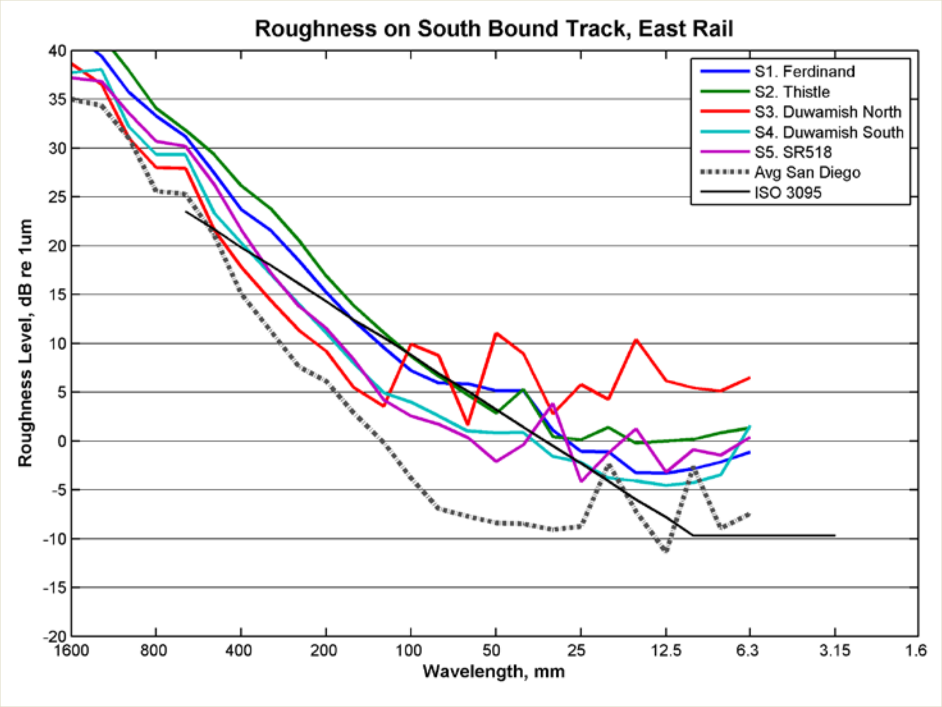
Rail Roughness Measurements

Measure vertical displacement in wear band over a small track section (typically 100 to 300m)

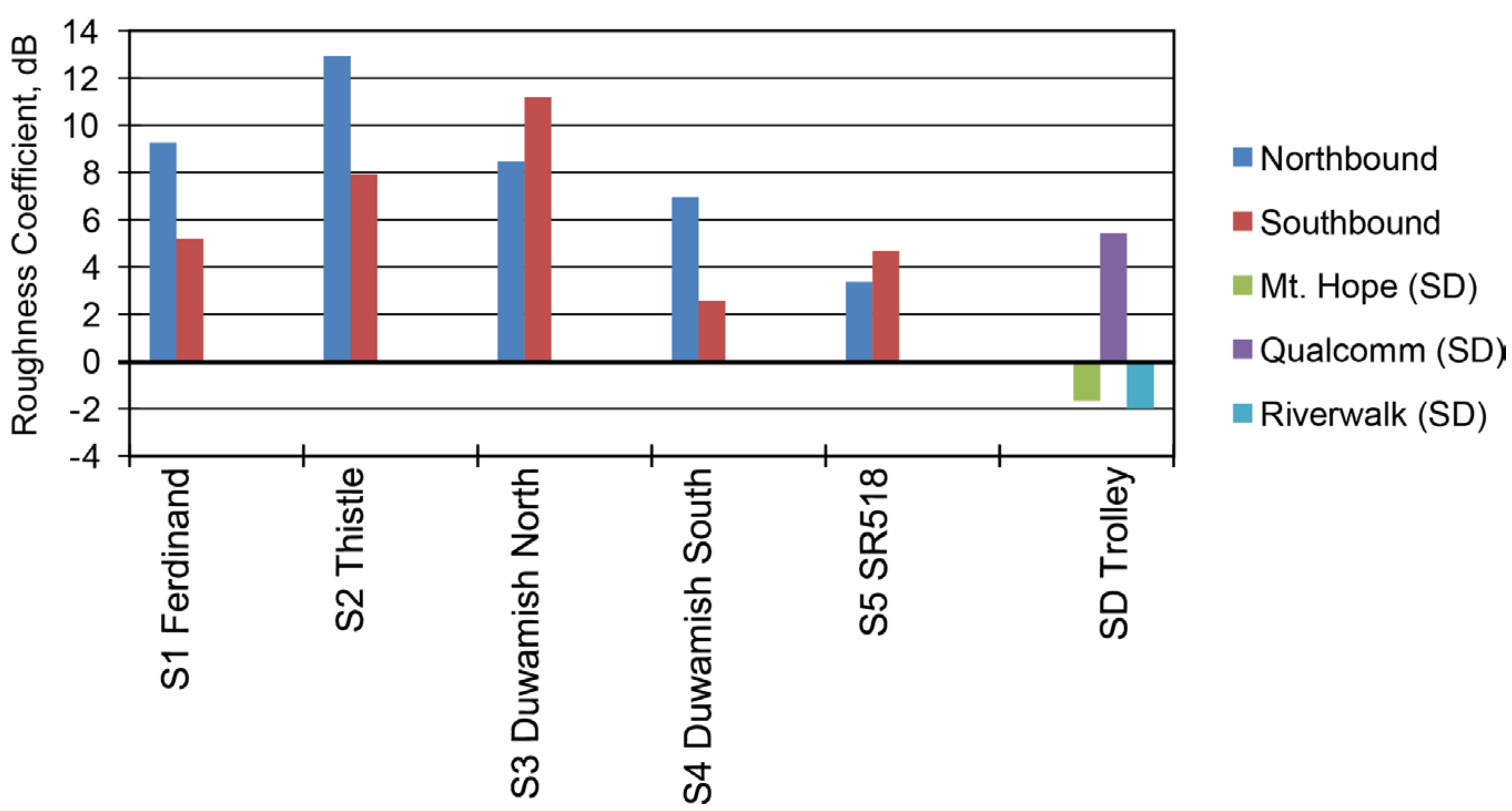


Average Roughness, 1/3 Octave Band Spectra





Derived Roughness "Coefficient"



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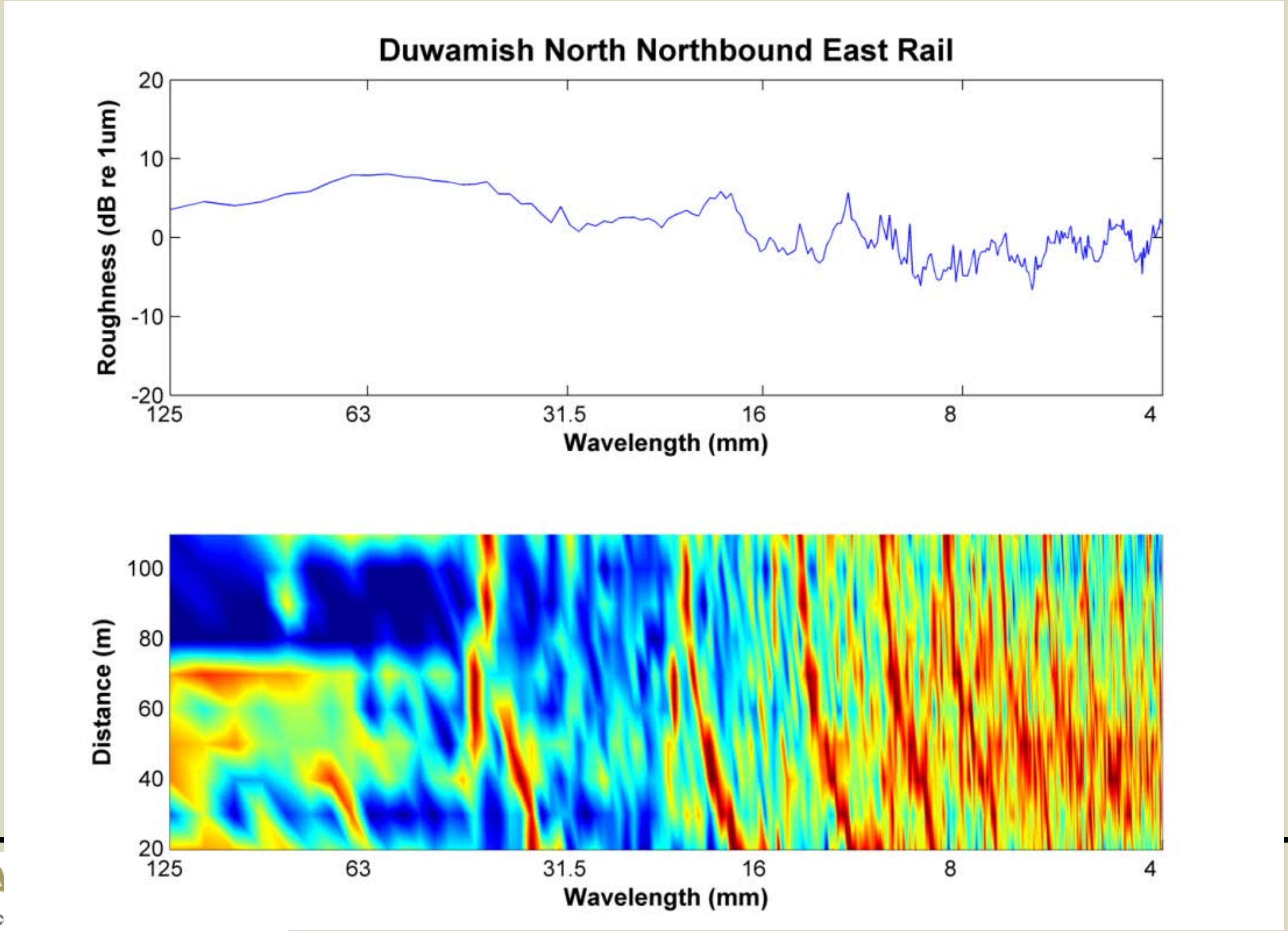
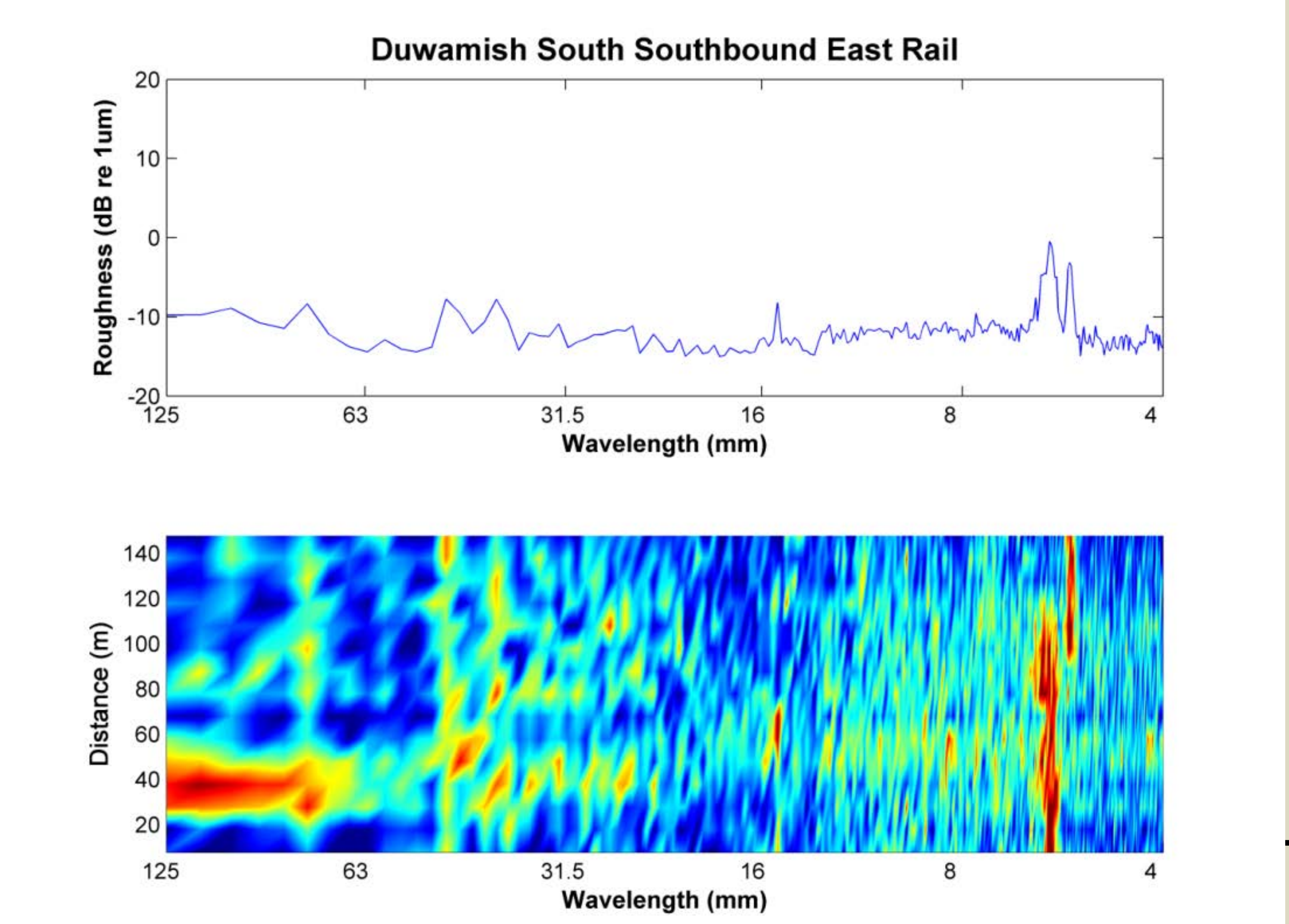
Roughness Spectrogram, Site 3



Roughness Spectrogram, Site 4



Close Proximity (1m) Noise Measurements

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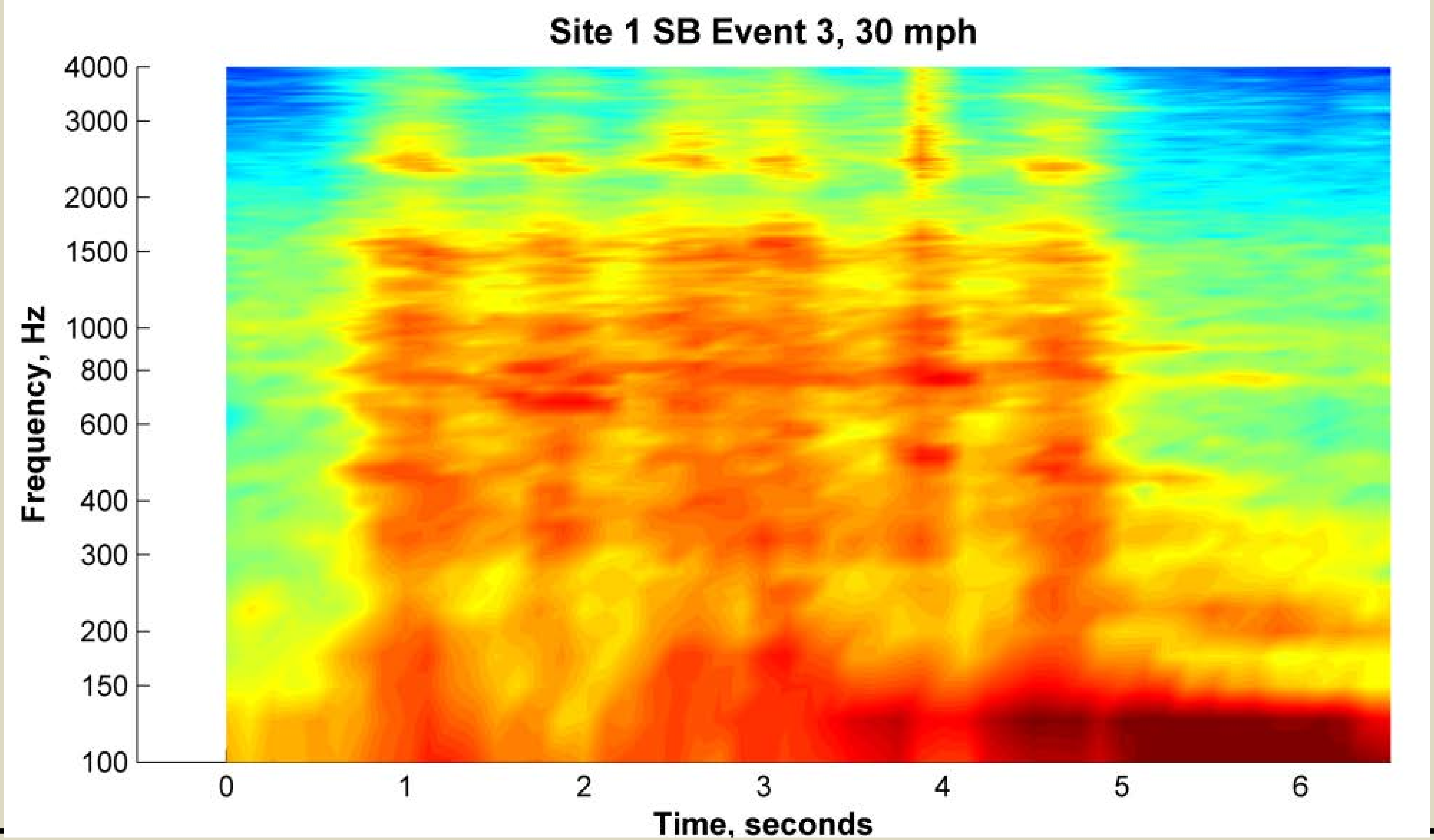
Is Noise from Wheel or Rail?

Example 1: Sound Transit Embedded track



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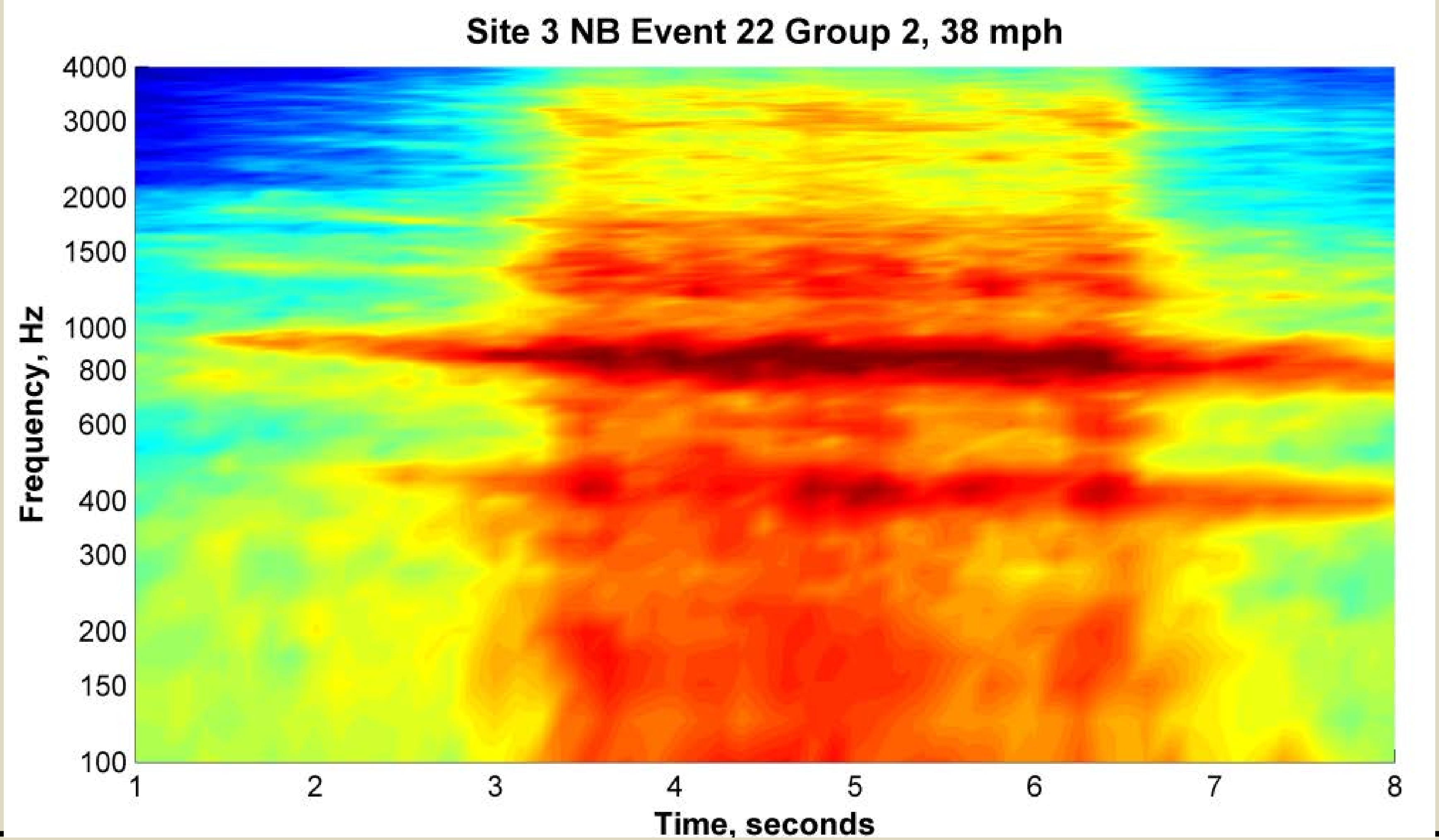
Is Noise from Wheel or Rail?

Example 2: Sound Transit Aerial Structure



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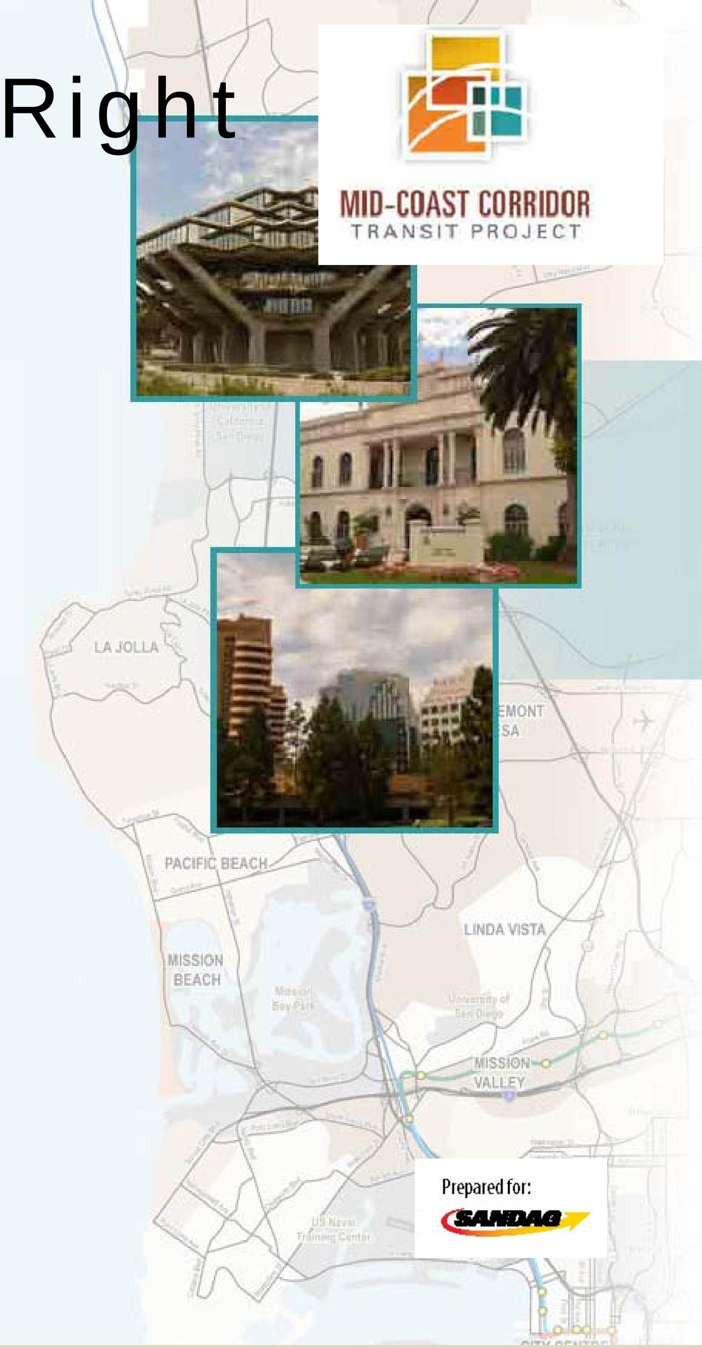
Conclusion from Close Proximity Measurements:

- Embedded track noise is dominated by noise radiated off of wheel
- Aerial structure noise is dominated by noise radiated off of rail
- Rail dampers may be effective at reducing noise on aerial structure

San Diego Trolley, the Right Way to Reduce Noise

- Environmental studies for Mid-Coast Corridor
- 11 Mile extension to San Diego Trolley from Old Town to University City
- Originally studied in early ‘90s.
- Projected:
  - o Start of Construction: 2015
  - o Operations: 2018



Noise Testing for Environmental Assessment

- Four locations, three ballast & tie, one aerial structure
- Three vehicle types
  - U2 and SD100 (high floor)
  - S70 (low floor)
  - US-S70 (low floor)
- Measurements:
  - Wayside noise
  - Train speed
  - Rail roughness

Site 2: Riverwalk Golf Course

Final San Diego Trolley Results

Site	Track Type	Lmax, dBA	
		S70/US-70	SD100
1	Ballast & Tie	--	77
2	Ballast & Tie	74	--
3	Ballast & Tie	73	75

- Values normalized to 40 mph, 50 ft from track centerline, and 2-car trains.
- FTA suggested reference level: 77 dBA, 40 mph, 50 ft, single car, ballast & tie track.
- Equivalent levels on other LRT systems as high as 83 dBA.

Bottom Line for Mid-Coast Analysis

- Justified using a reference level of 75 dBA
- 2 dB lower than FTA recommendation
- Substantially lower than recently measured on similar LRT systems.
- Amount of noise mitigation (sound walls) substantially reduced.
- Lower reference level might be reasonable.

Overall Conclusions

- Tools are available for analyzing rolling noise
- Relatively simple measurements can lead to insights on where treatments are needed and what treatments will work
- Proper maintenance will result in lower noise levels
  - Specification is needed for rail grinding
  - Problem areas can be identified with on-board measurements
  - Problem wheels need to be identified and trued
- If San Diego Trolley can have low noise levels, why not all other transit systems?