

Wheel-Rail Interface Conference

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Using on-board & wayside noise measurements to monitor track condition and prioritize rail grinding

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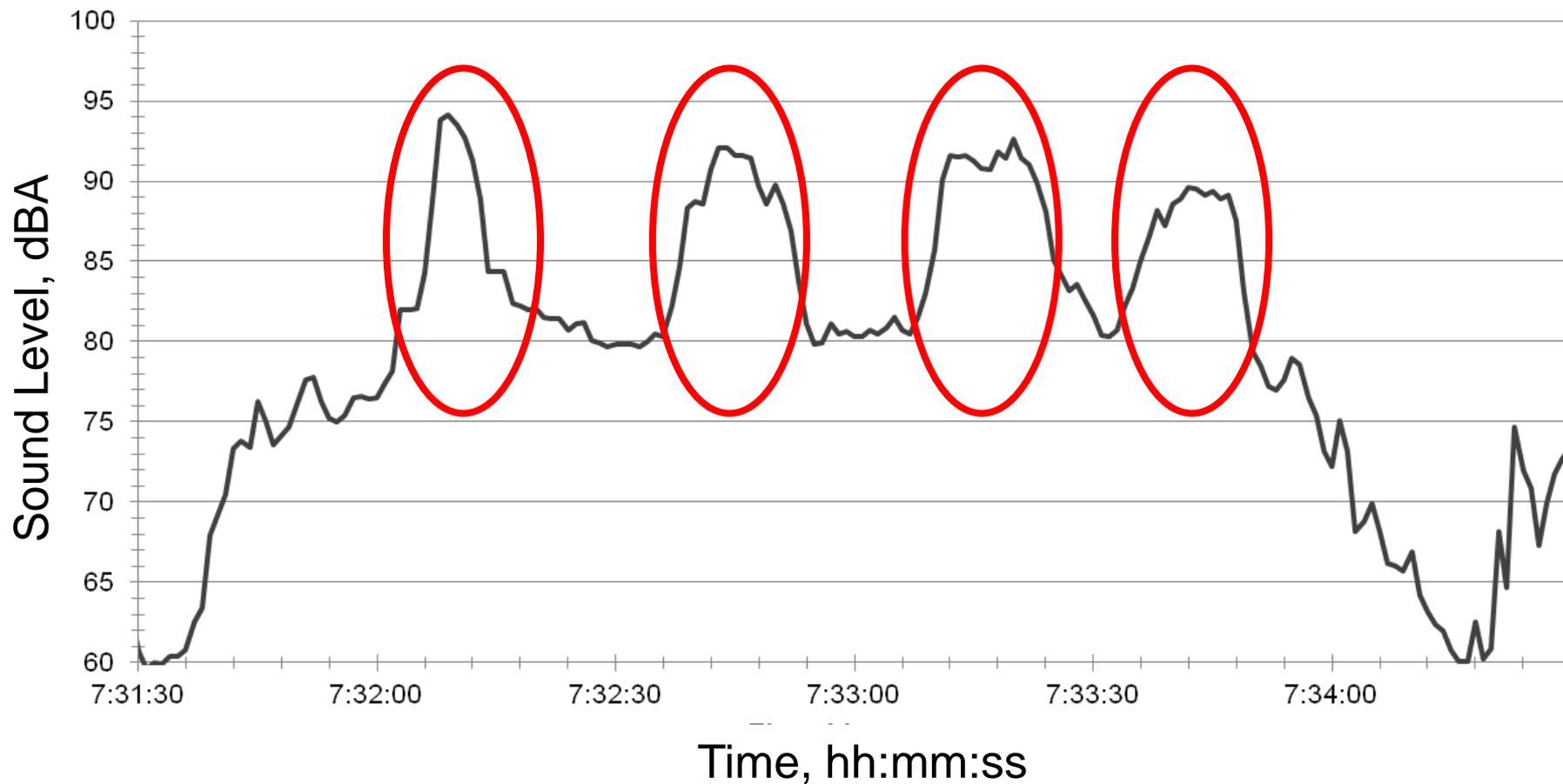
Outline

- Background
 - Terms
 - How to read the figures
- ATS Corrugation projects
- Case Study:
 - Long term corrugation and noise monitoring on BART
- Conclusions and Future Extensions



On-Board Noise Measurement, 2003

In-Car Noise, San Bruno to South San Francisco



Why is rolling noise on one system louder than another?

- Corrugation
- General condition of wheels and rails
- Vehicle characteristics (e.g., wheel skirts)
- Track structure (e.g., rail vibration decay rate)
- Properties of wheels (e.g., solid vs. resilient)
- Wheel and rail profiles
- Lubrication



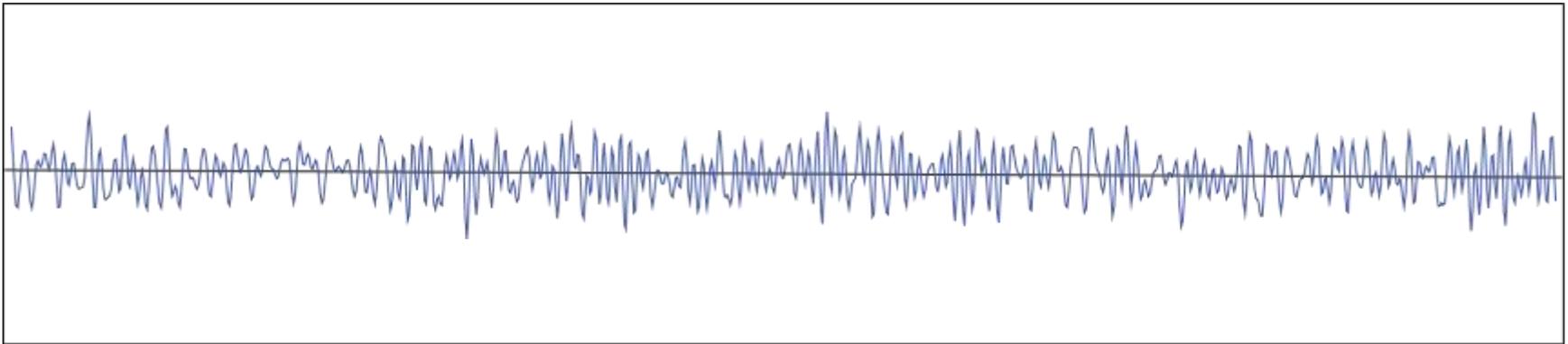
Background

- ATS has worked to detect corrugation at several systems
- Many approaches to solving problem
- What works in one location may not work elsewhere
- Factors thought to contribute to corrugation include
 - Slip-stick between wheels and rail
 - Wheel and rail profiles
 - Tightness/looseness of gauge
 - Curve vs. tangent track
 - Tightness of curves
 - Metallurgy (micro and macro)
 - Other...



“Random” *Roughness from wear*

Random Roughness



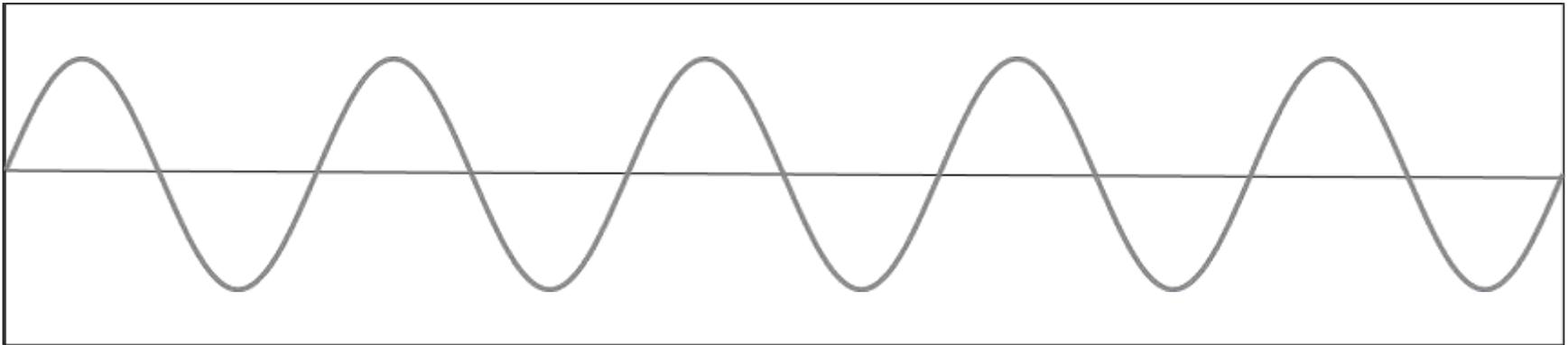
$$\begin{aligned} \text{frequency} &= \text{speed} / \text{wavelength} \\ &= 17.9 \times \text{speed}(\text{mph}) / \text{wavelength}(\text{inches}) \\ &= 447 \times \text{speed}(\text{mph}) / \text{wavelength}(\text{mm}) \end{aligned}$$



“Corrugation”

Sinusoidal pattern induced in the rail by normal vehicle operations

Corrugation



$$\text{frequency} = \text{speed} / \text{wavelength}$$

$$= 17.9 \times \text{speed}(\text{mph}) / \text{wavelength}(\text{inches})$$

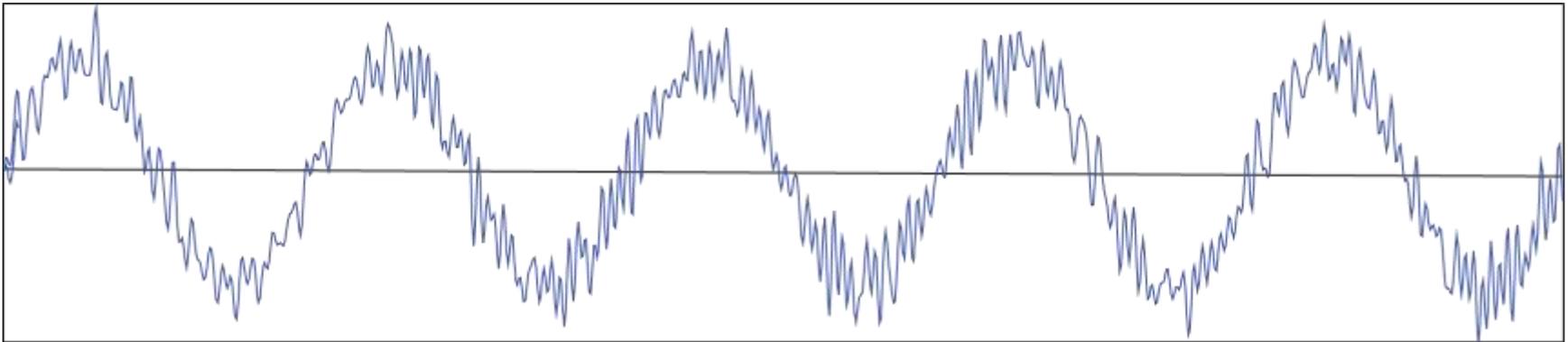
$$= 447 \times \text{speed}(\text{mph}) / \text{wavelength}(\text{mm})$$



“Roughness”

Any longitudinal irregularity in rail surface

Combined Corrugation and Random



frequency = speed / wavelength

= 17.9 × speed (mph) / wavelength (inches)

= 447 × speed (mph) / wavelength (mm)



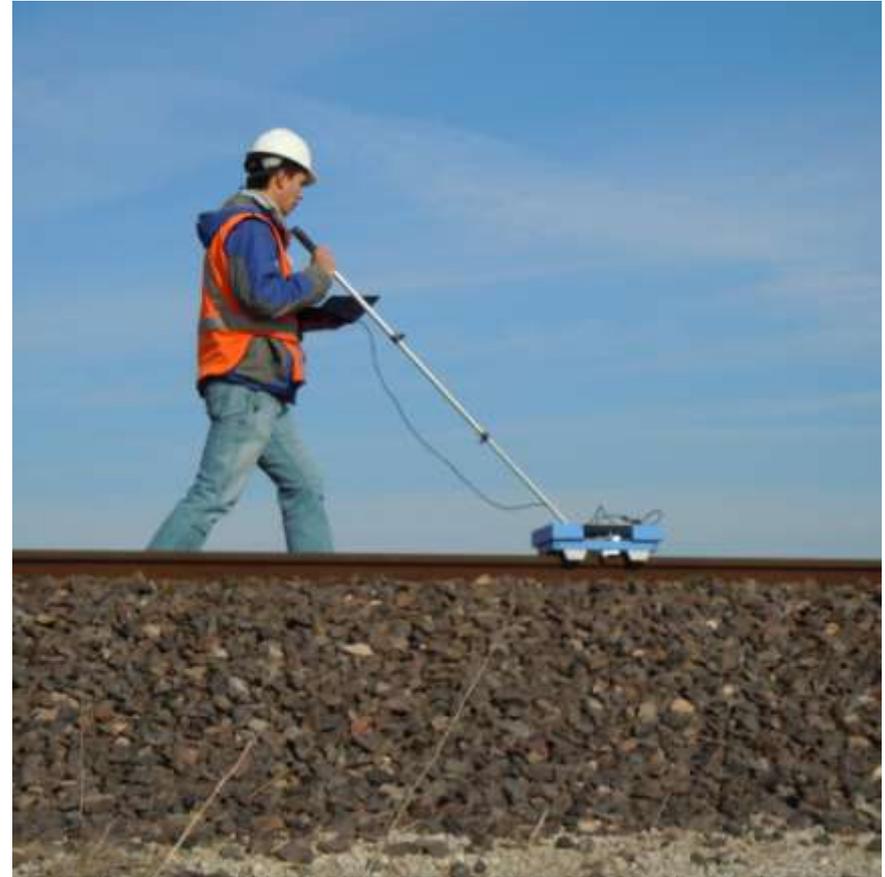
Recent ATS Experience

- **St. Louis Metrolink:** Identify problem spots to prioritize grinding
- **Seattle Sound Transit:** Wheel rail study to diagnose higher than expected noise levels
- **Los Angeles Metro:** Noise complaint troubleshooting
- **Bay Area Rapid Transit:** Long term study: rail corrugation and dampers
- **San Diego Metropolitan Transit System:** Quality control for grinding
- **Minneapolis Metro Transit:** Full system measurement prior to identify locations for grinding
- **New York AirTrain:** Site specific measurements prior to grinding
- **Sacramento Regional Transit:** Site specific measurements before/after grinding, determine noise reduction that could be achieved with improved grinding and wheel truing procedures

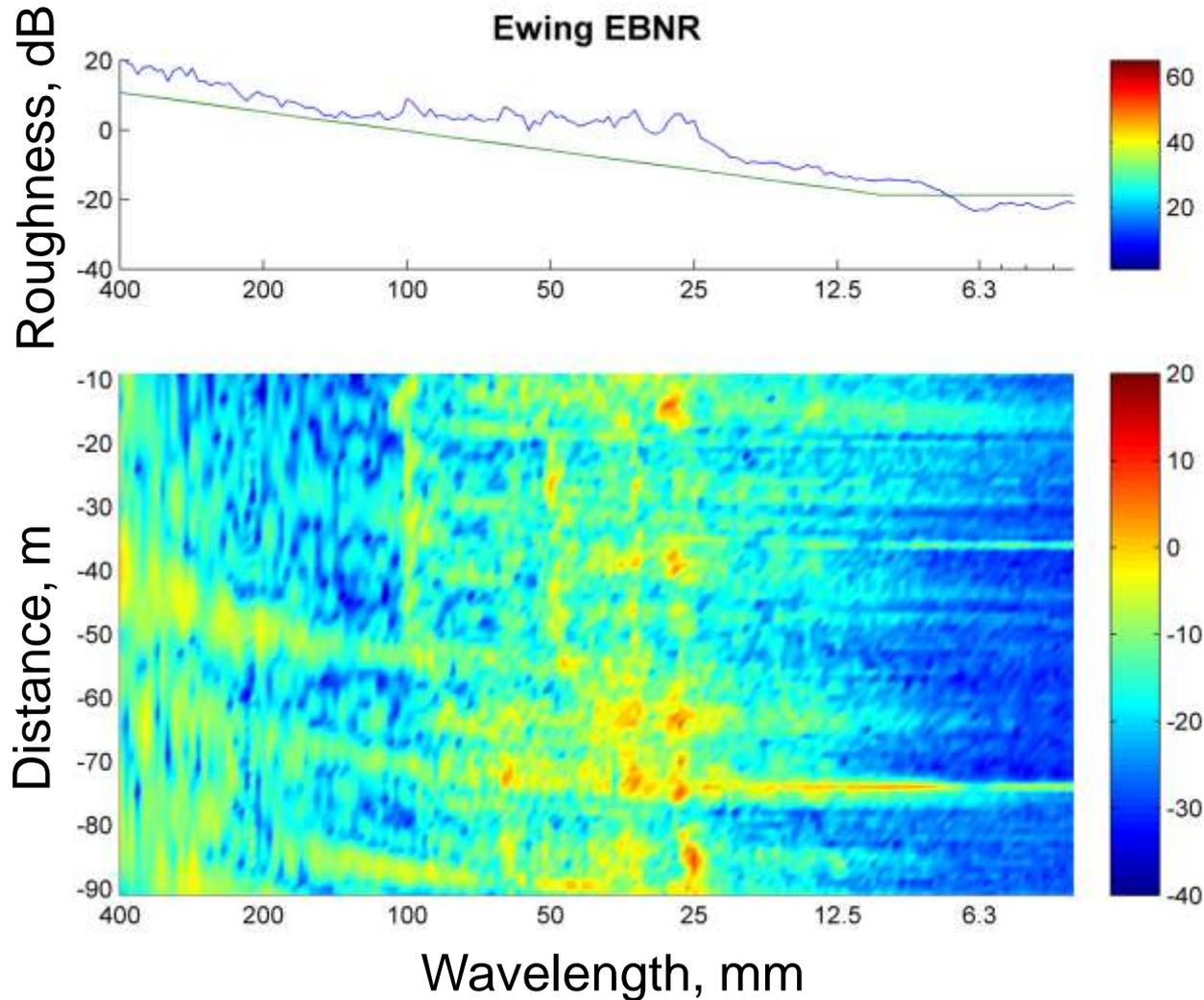


Direct Roughness Measurement

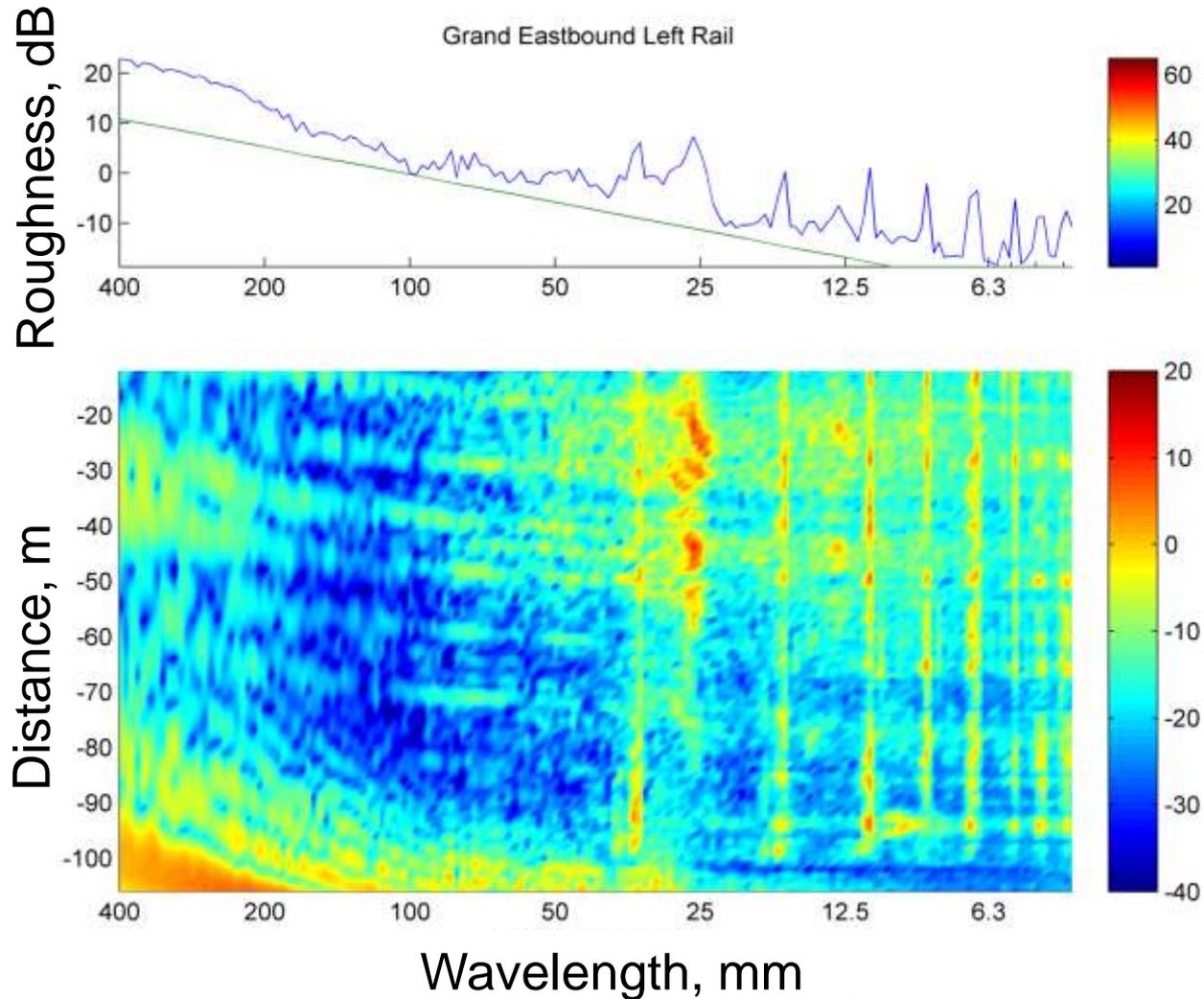
- Small cart measures the rail head
- Can measure wavelengths as short as 2 mm
- Typically measure distances up to 200m



St. Louis Before Grinding



St. Louis After Grinding



Wayside Noise

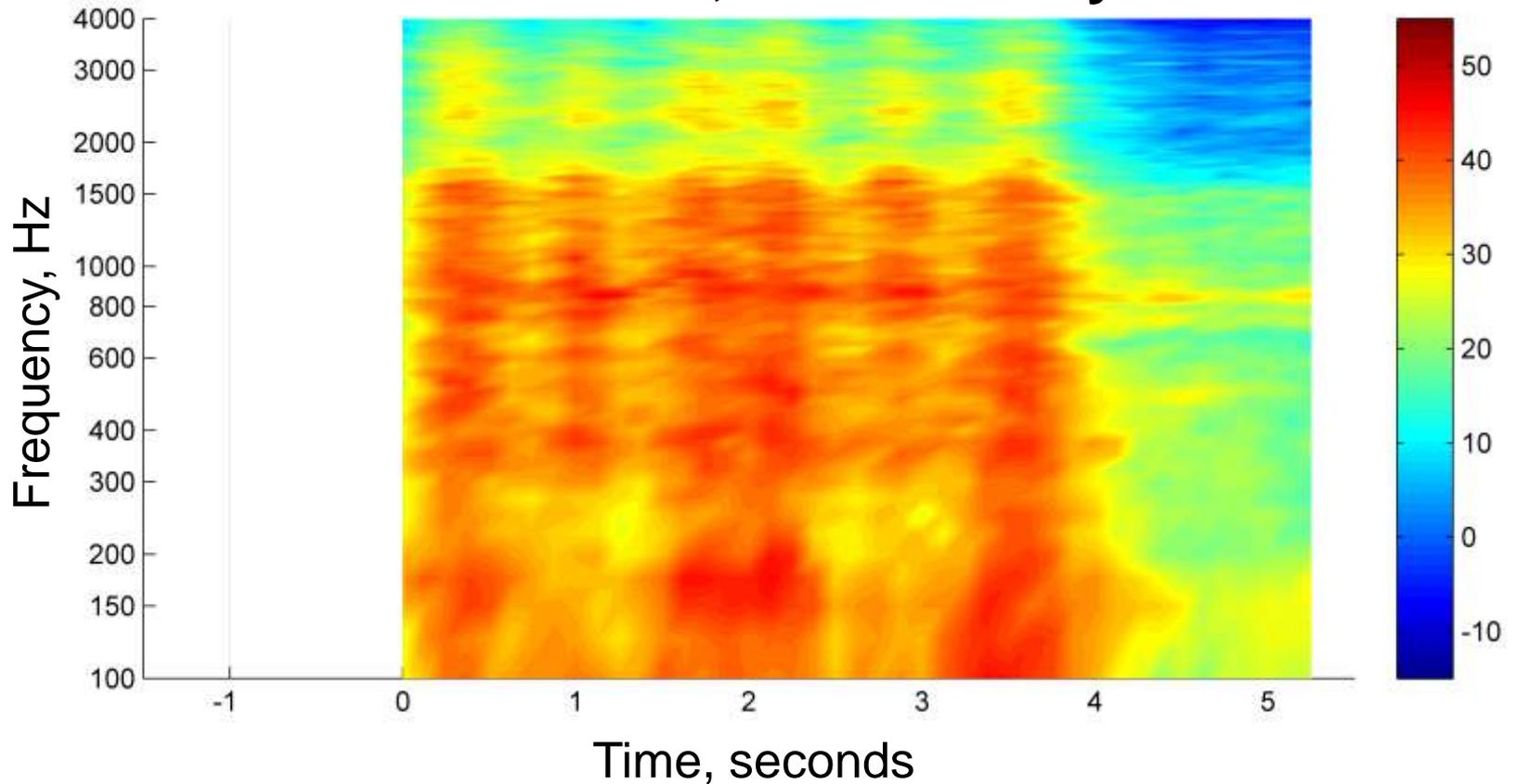


- Microphones placed at the track wayside
- Distances of 1m, 7.5m, 15m
- Measure noise as trains pass measurement position



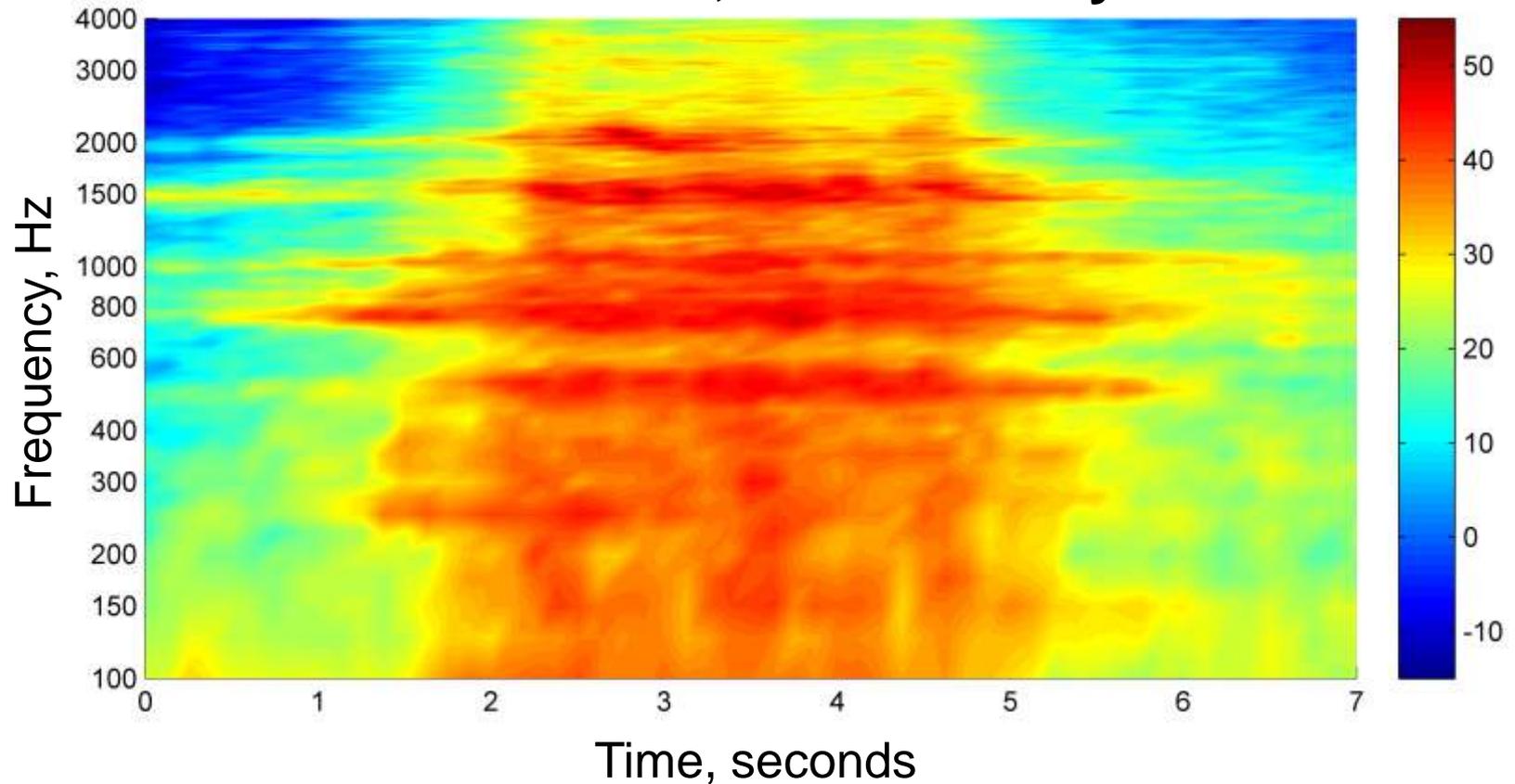
Seattle Wayside Noise

Train Noise, 1 meter away



Seattle Wayside Noise

Train Noise, 1 meter away



On-board Noise Measurements

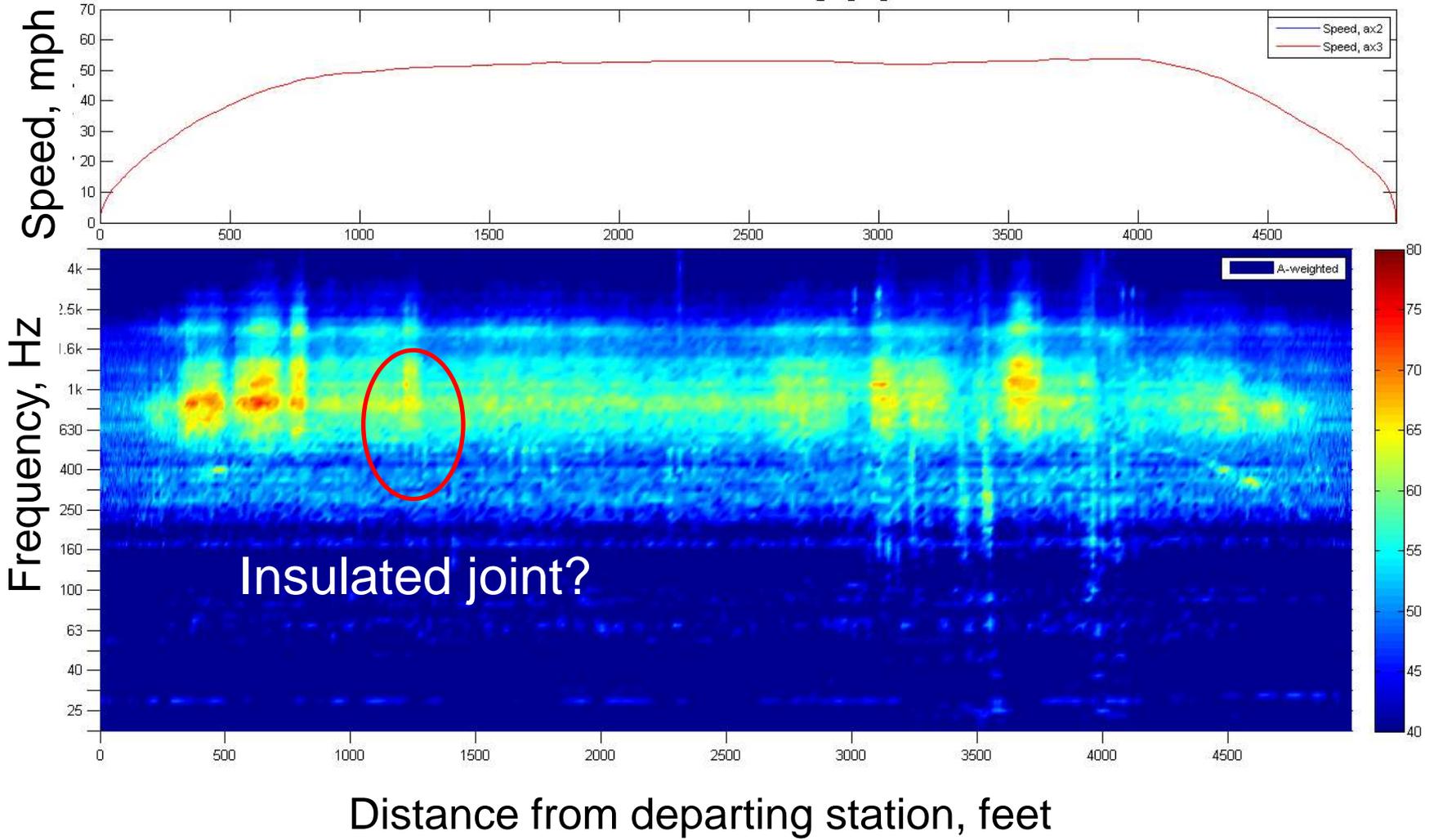


- Fast setup
- Mounts easily in cab
- Works in tunnels
- Full wave playback
- One-man crew
- Representative of rider experience
- Examine entire system quickly



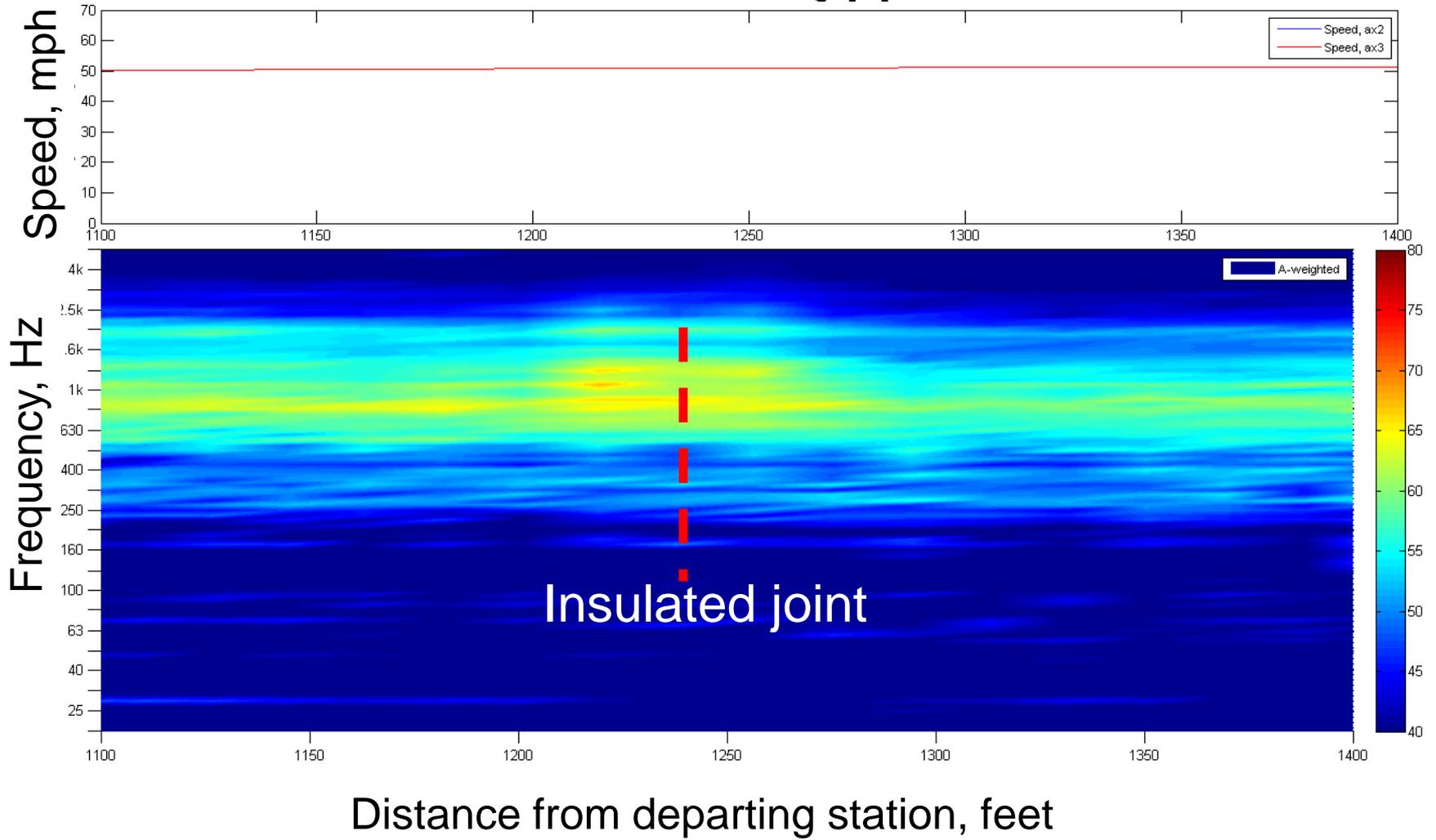
LA Expo On-board Noise

La Brea » La Cienega [10]



LA Expo On-board Noise

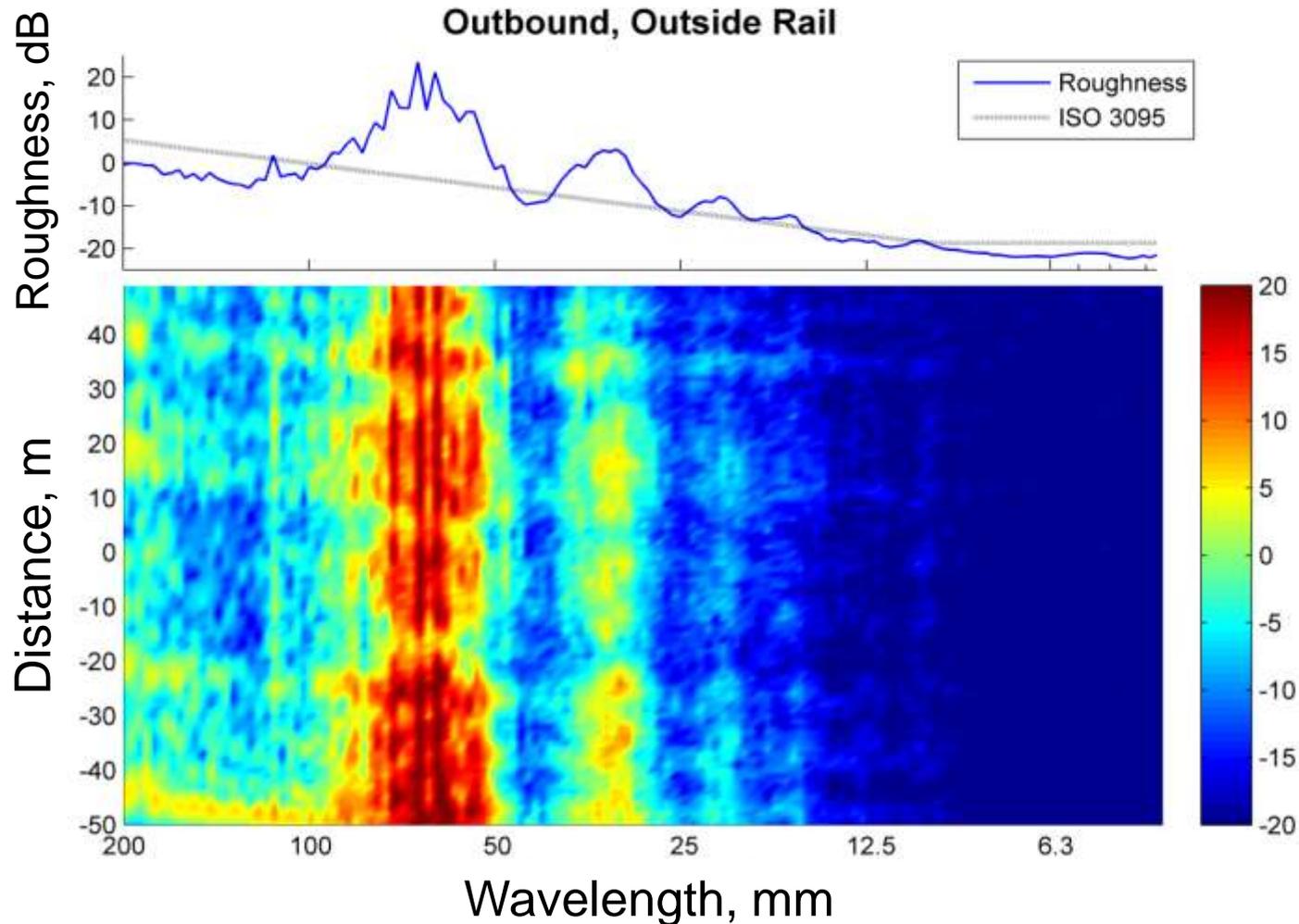
La Brea » La Cienega [10]



Rail Head Near Insulated Joint



BART Aerial Structure



BART Aerial Structure



Monitoring System Wide Corrugation at BART

Goal:

- Prioritize locations for rail grinding
- Optimize rail grinding efforts
- Search for parameters that correlate with corrugation (track type, curvature, fastener type, speed, gauge, wear, ...)
- Monitor corrugation growth

Approach:

- “On-board” Noise measurements in trailing vehicle operator’s cab



Addressing Corrugation at MP 7.1

Goal:

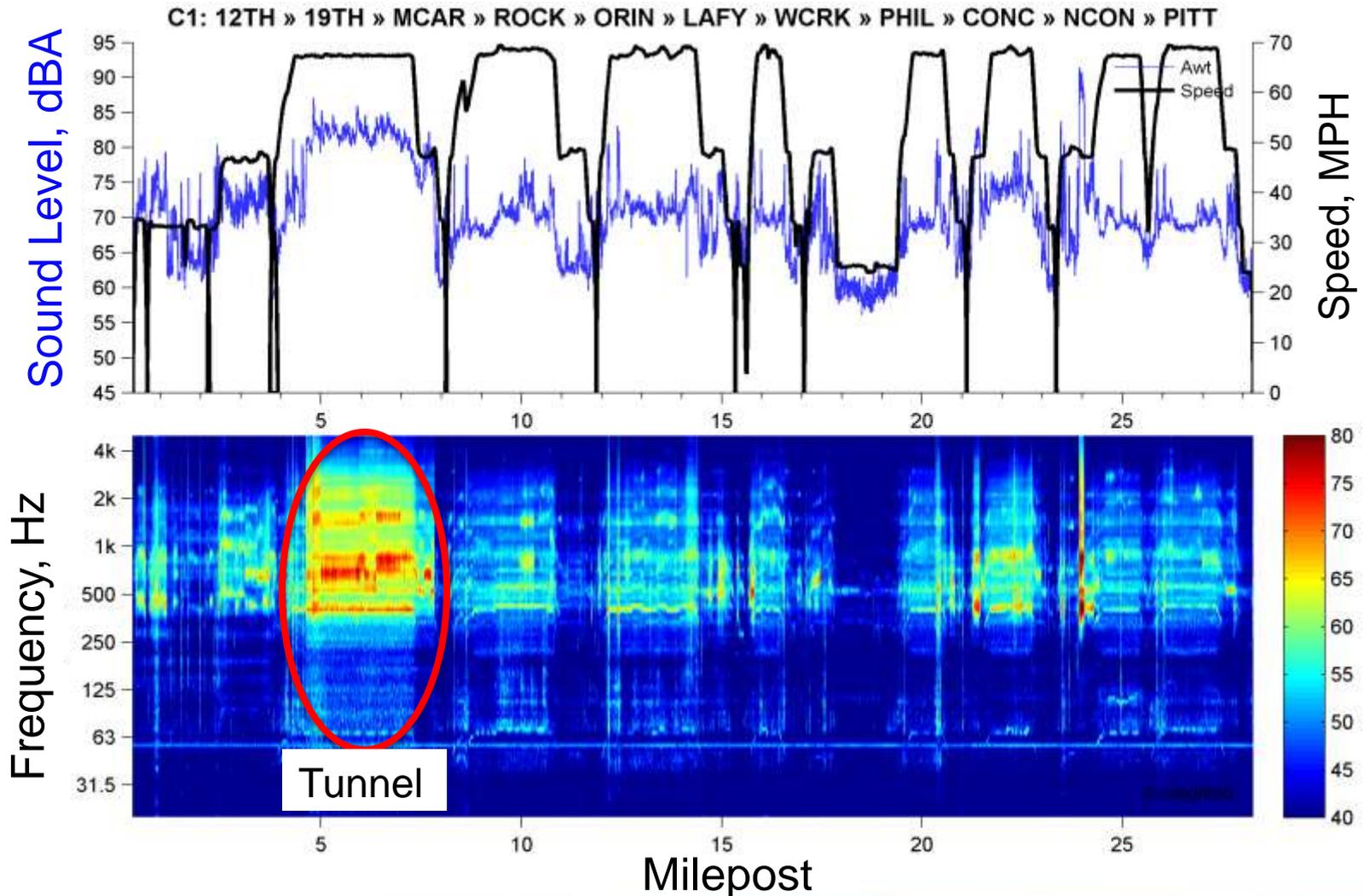
- Monitor noise levels over time
- Quantify effectiveness of rail grinding
- Quantify effectiveness of rail dampers
- Monitor growth of rail corrugation with and without rail dampers
- ***Find a solution to rail corrugation!!***

Approach:

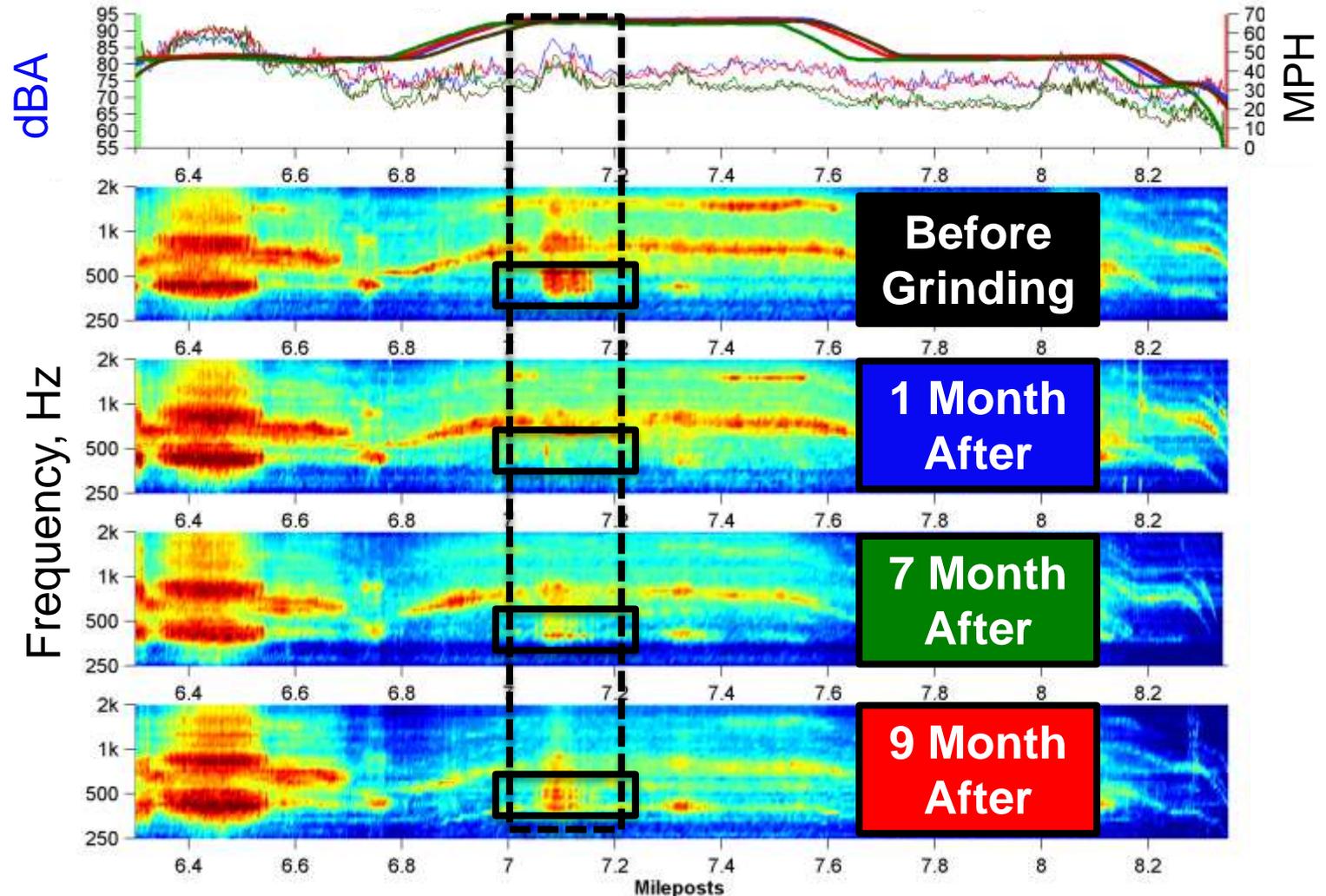
- On-board noise, wayside noise, and rail roughness
- Test rail dampers
- Examine rail grinding procedures (ARM)



Visual Overview by Track

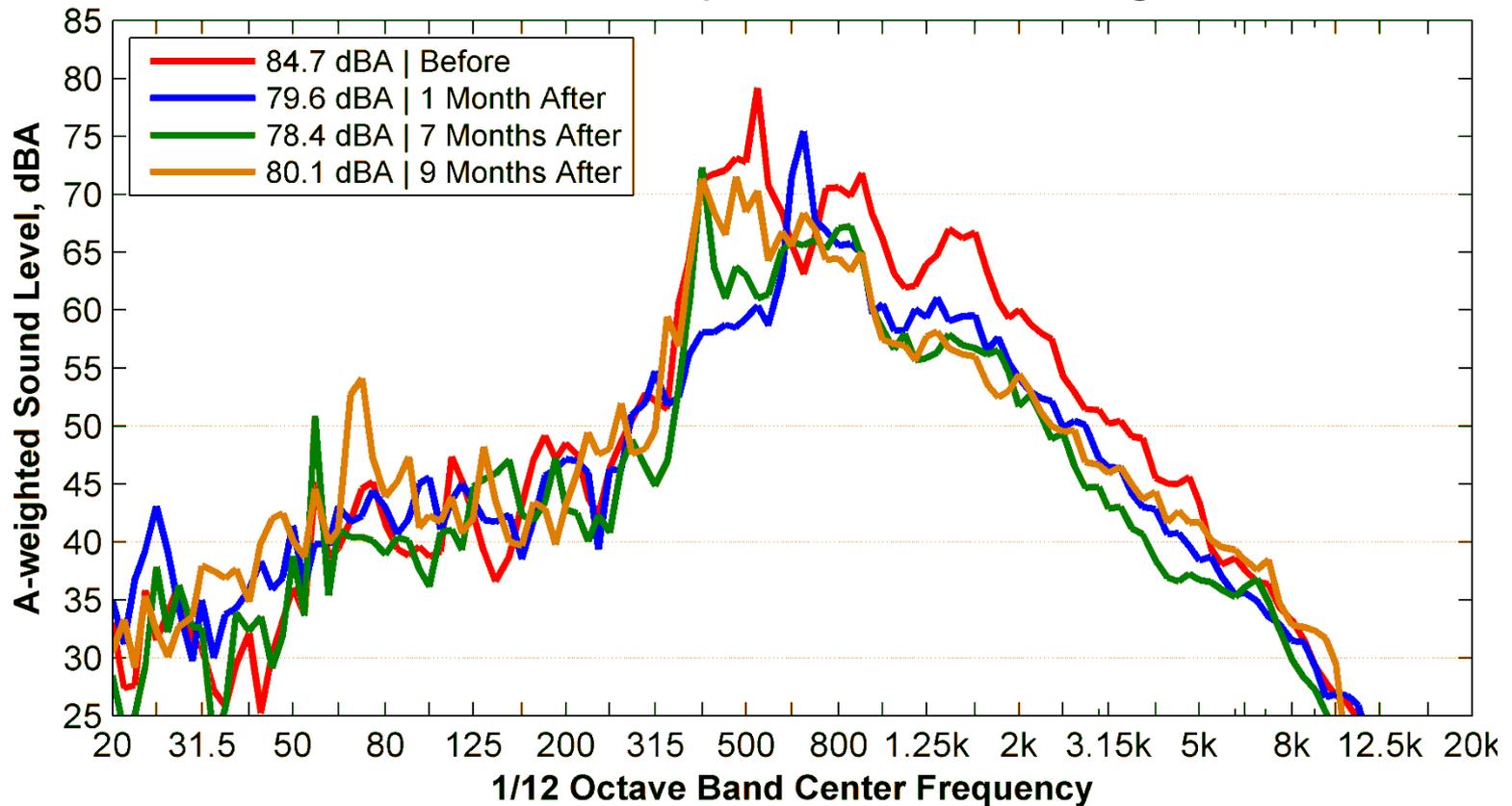


Tracking Corrugation Growth Using Onboard Noise

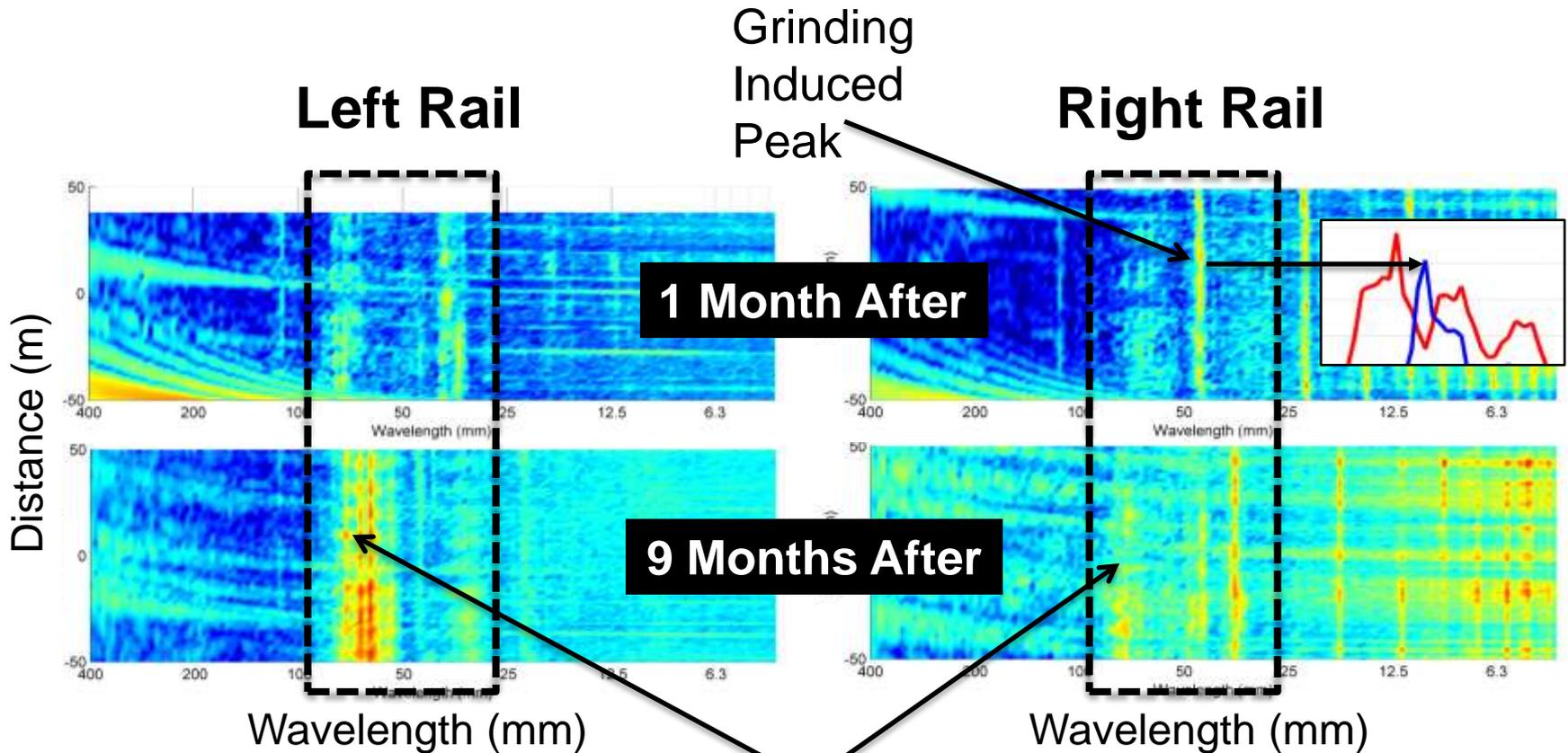


Tracking Corrugation Growth Using On-Board Noise

Onboard Train Noise Spectrum at Grinding Location



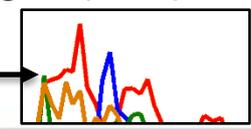
Tracking Corrugation Growth Using Rail Roughness Measurements



1 Month After

9 Months After

$75 \text{ mm} = 447 * 67\text{mph} / 400 \text{ Hz}$



Quantify Effectiveness of Rail Dampers

- Installed January 2013
- Rail ground March 2013
- Corrugation growth tests have not been performed

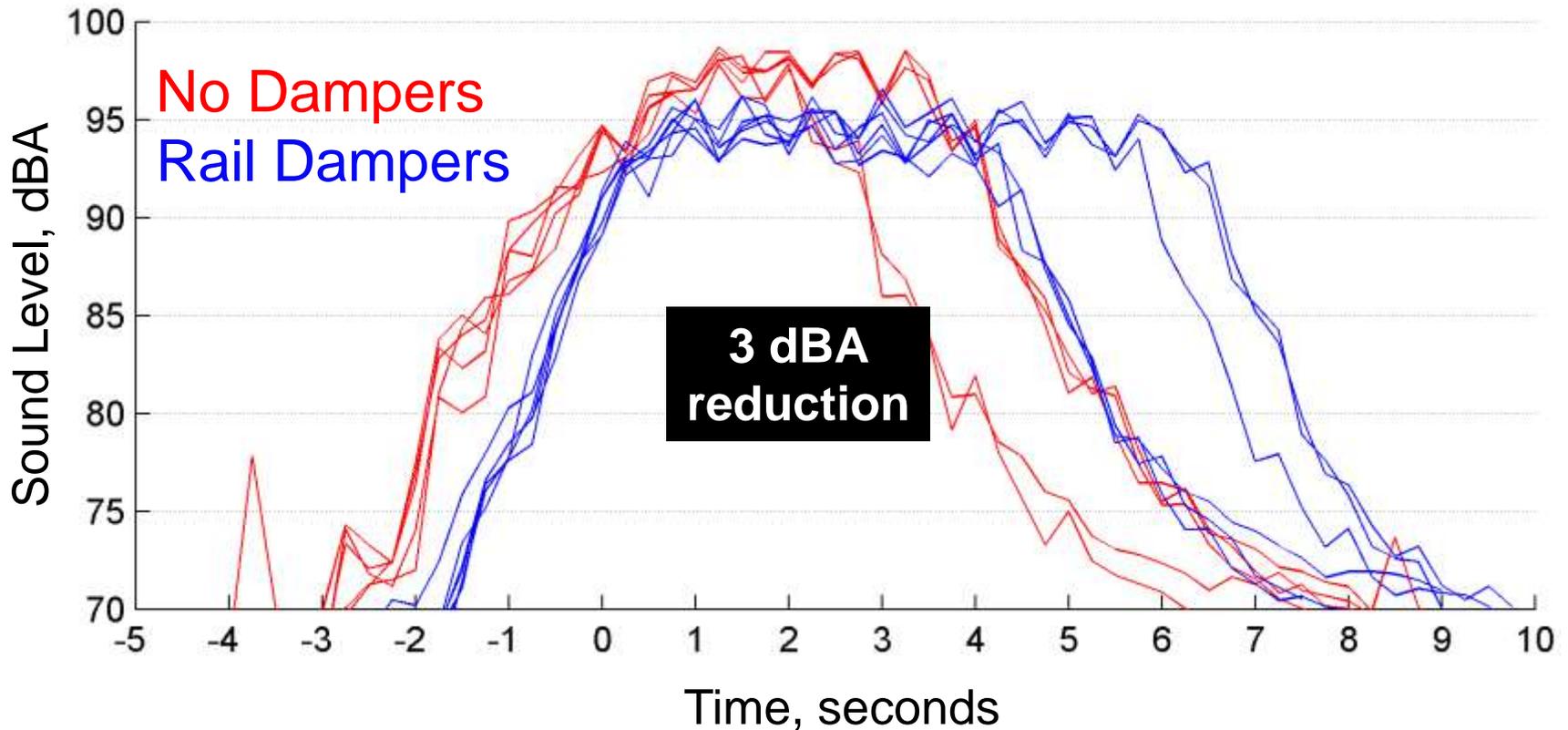


Wayside Noise Setup

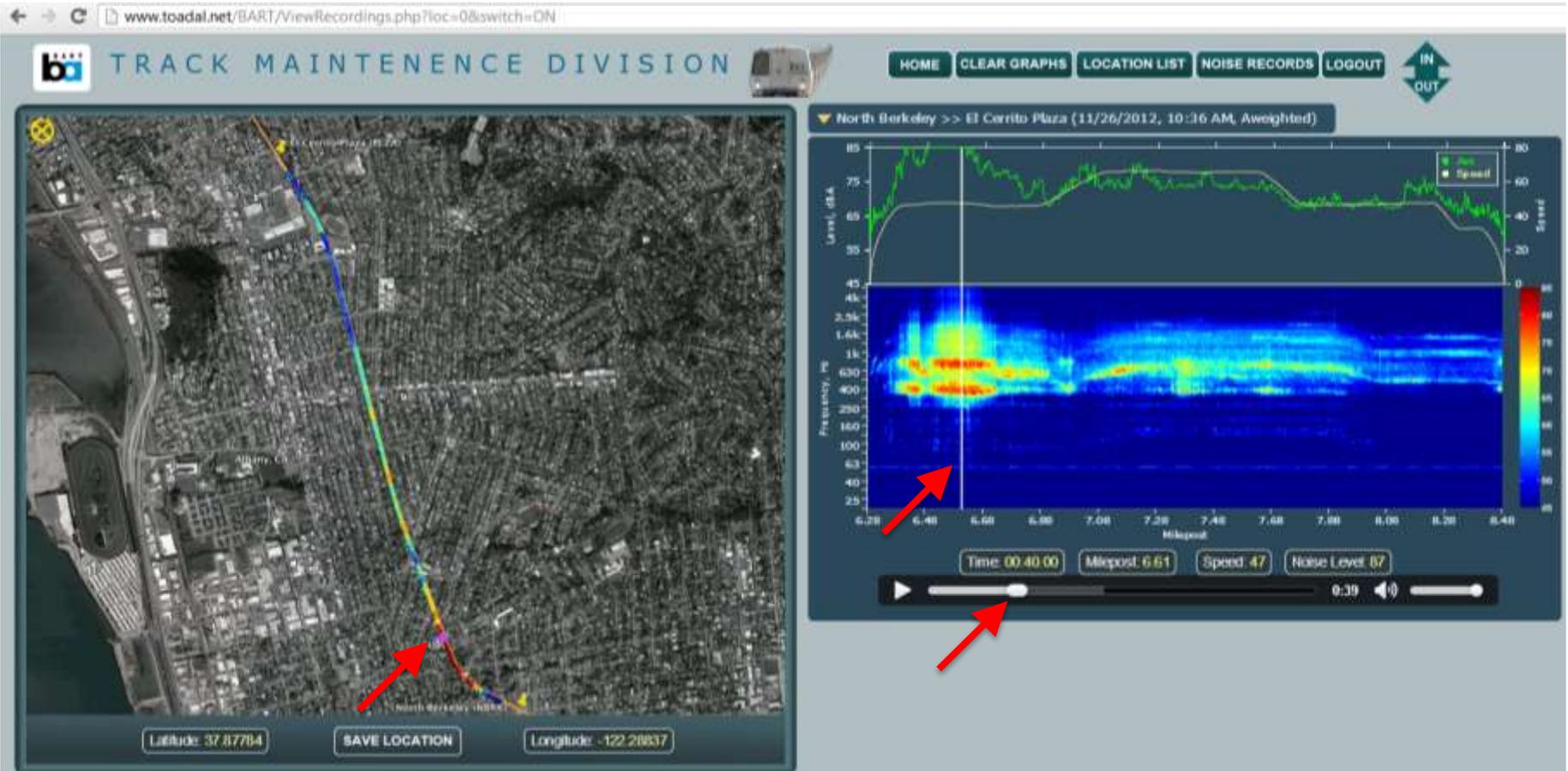


Rail Dampers' Effectiveness Using Wayside Noise

Time Histories of Train Noise 7½ meters from rail



Web App for BART



Conclusions

- Tools for identifying and tracking corrugation and noise problems include:
 - On-board noise or vibration measurements
 - Rail roughness measurements
 - Wayside noise measurements 1m to 15m from track (3.3 ft to 50 ft)
- 3D, GIS, and animated displays:
 - Allow visualizing large quantities of data
 - Lead to insights
 - Help explain conclusions to non-technical audiences



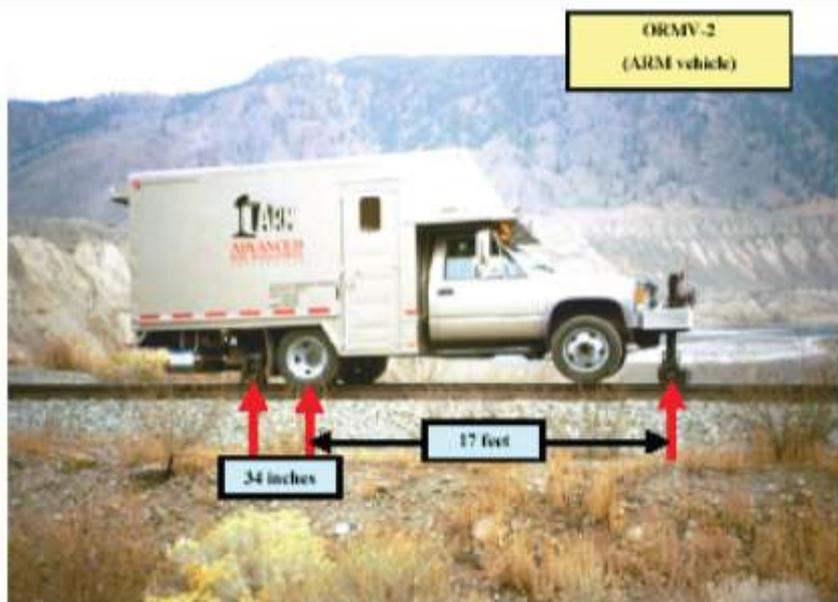
Extensions to BART Web App

(joint effort by ATS, ARM and TOADAL.net)

- Animation of Rangecam rail profile measurements
- Synchronize with relevant track data
- Links to other data (e.g., rail grinding database, complaints, ...)



Track Geometry Measurements

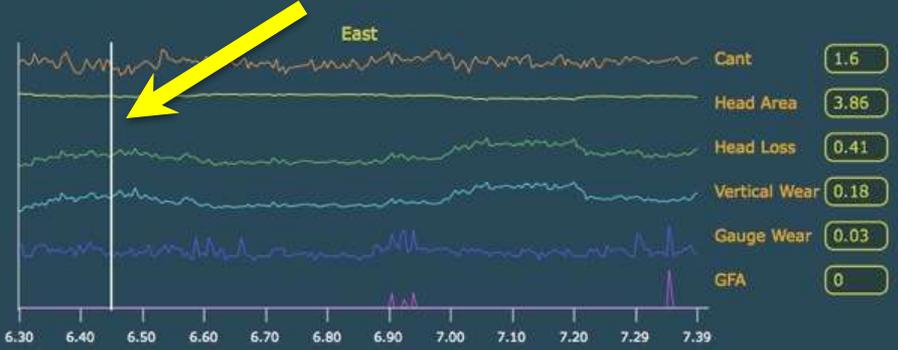
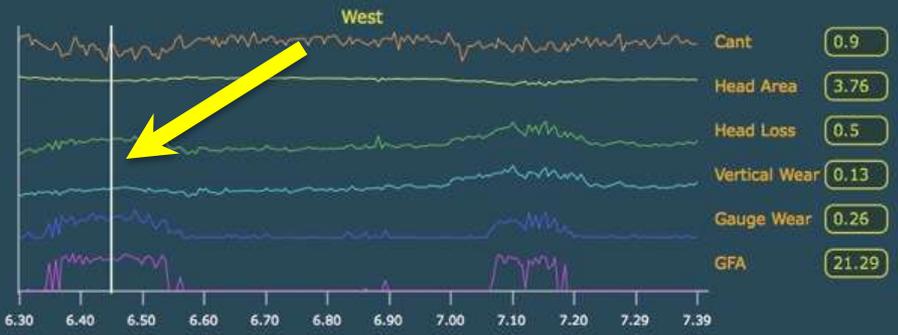
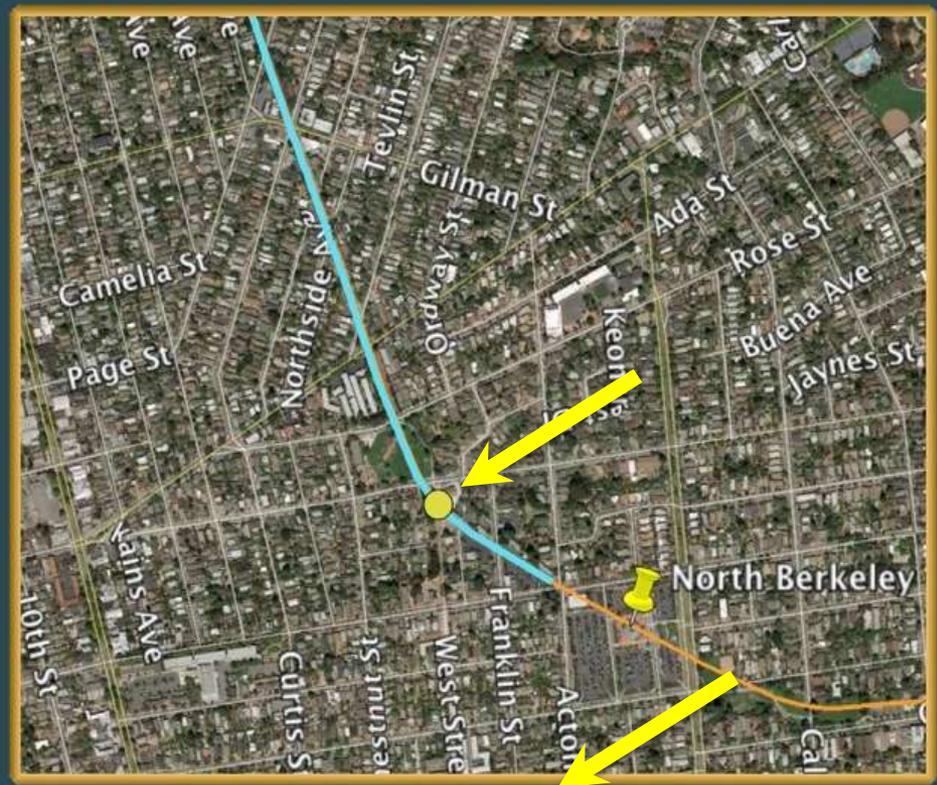


Vehicle Mount



Buggy Mount

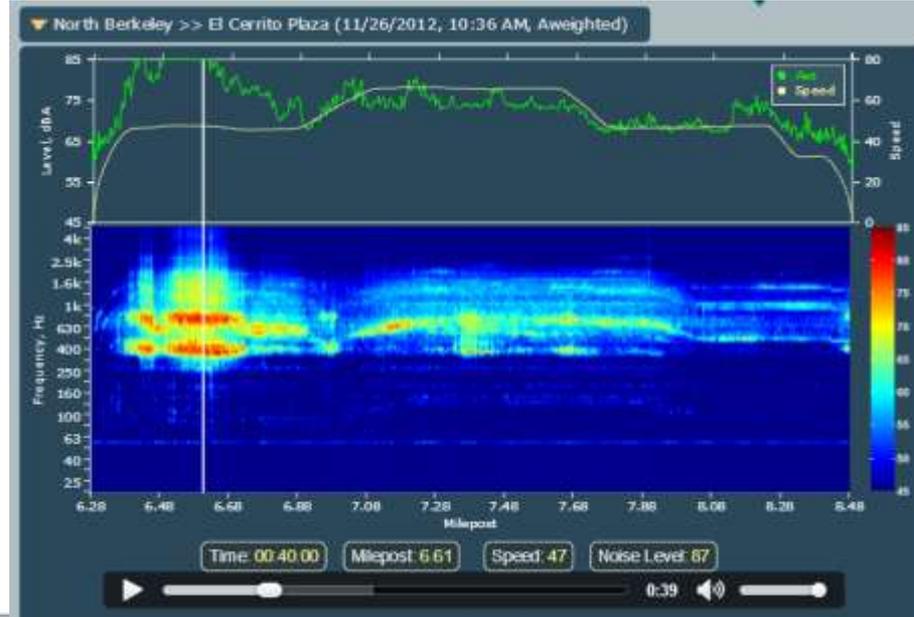
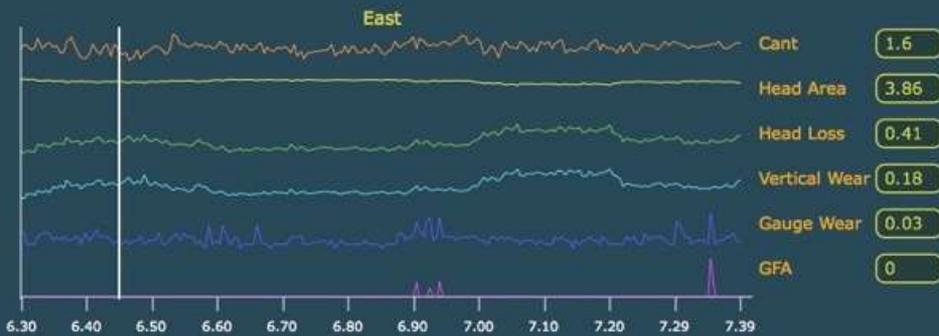
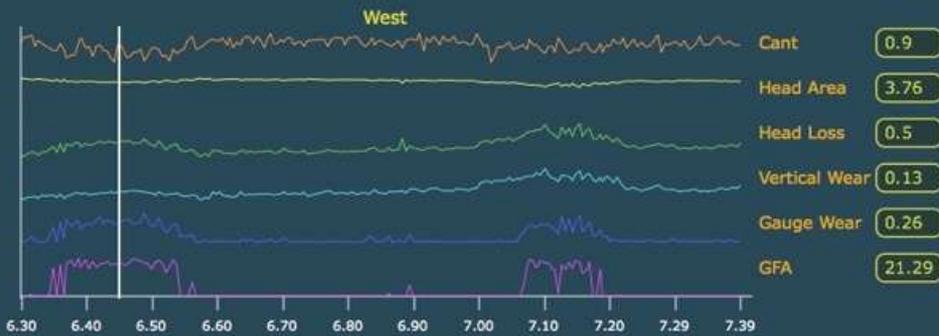
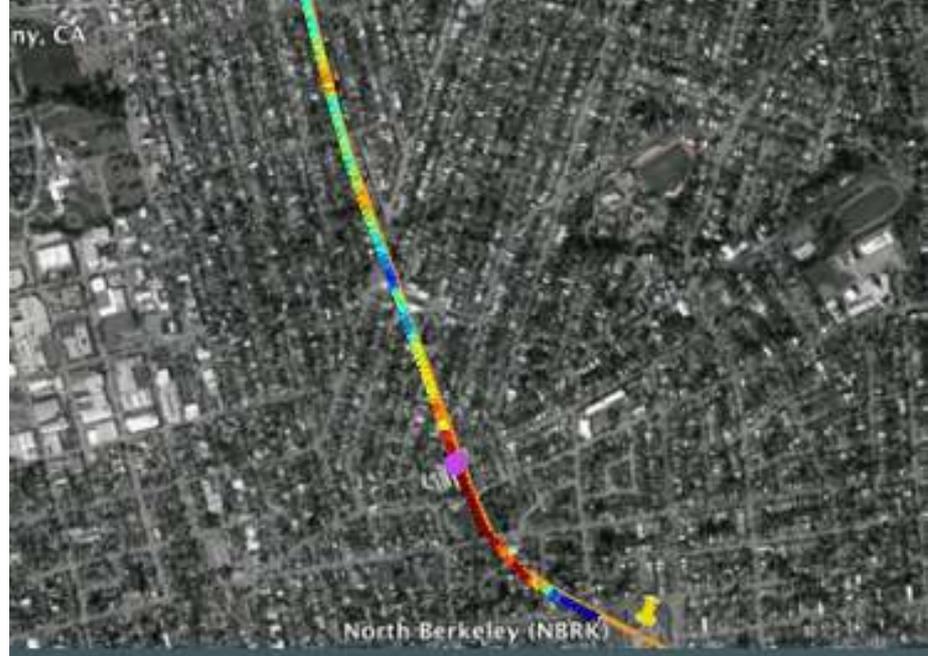




RAIL PROFILE ANALYZER

Brought to you by ATS Consulting, Advanced Rail Management, and TOADAL.net





Questions?

