

Low Frequency Vibration Control from Sound Transit under the University of Washington

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Sound Transit



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2010 RAIL CONFERENCE

Sound Transit North Link

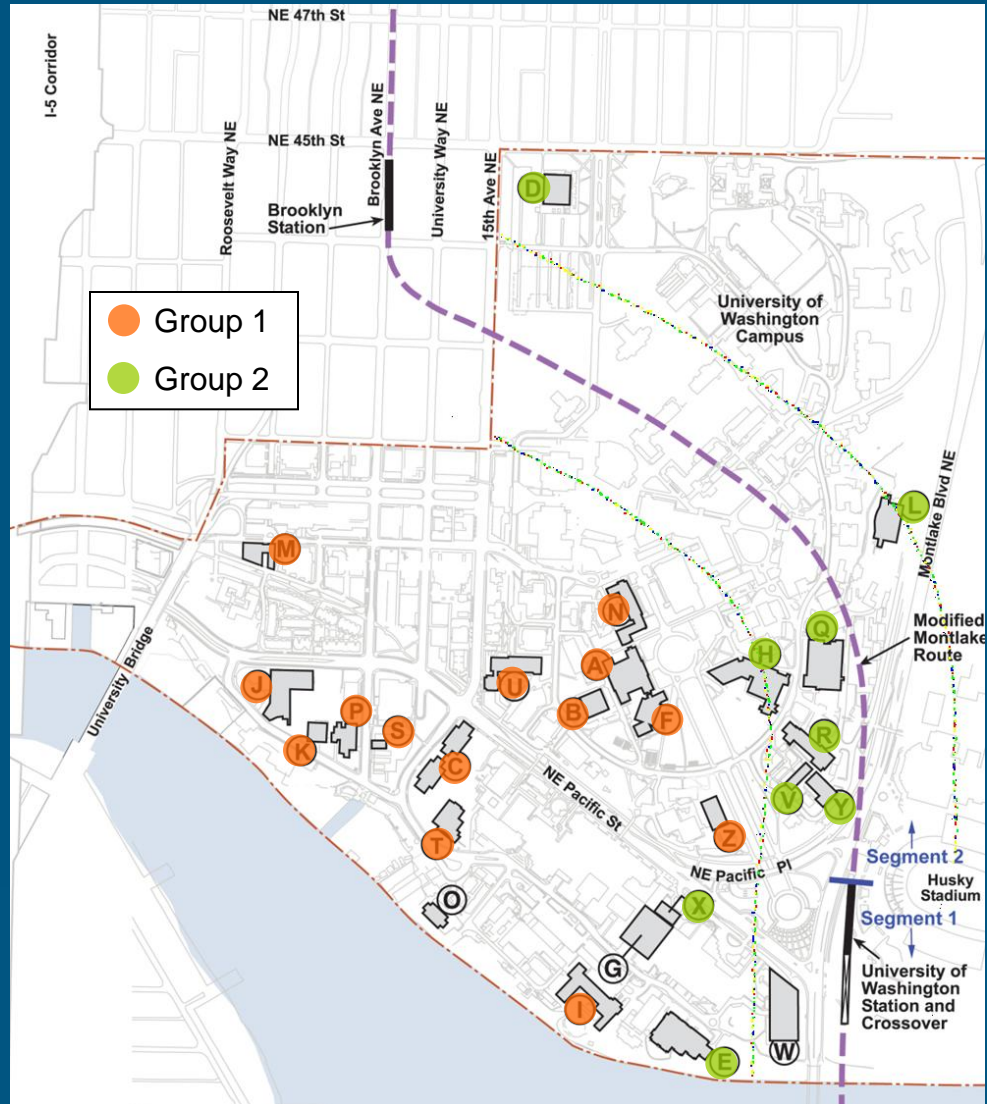
- Extends subway from downtown Seattle
 - 6.5 miles in tunnel
 - 1 mile at-grade/aerial
 - U-Link / North Link
- Revenue service
 - U-Link: 2016
 - North Link: 2020



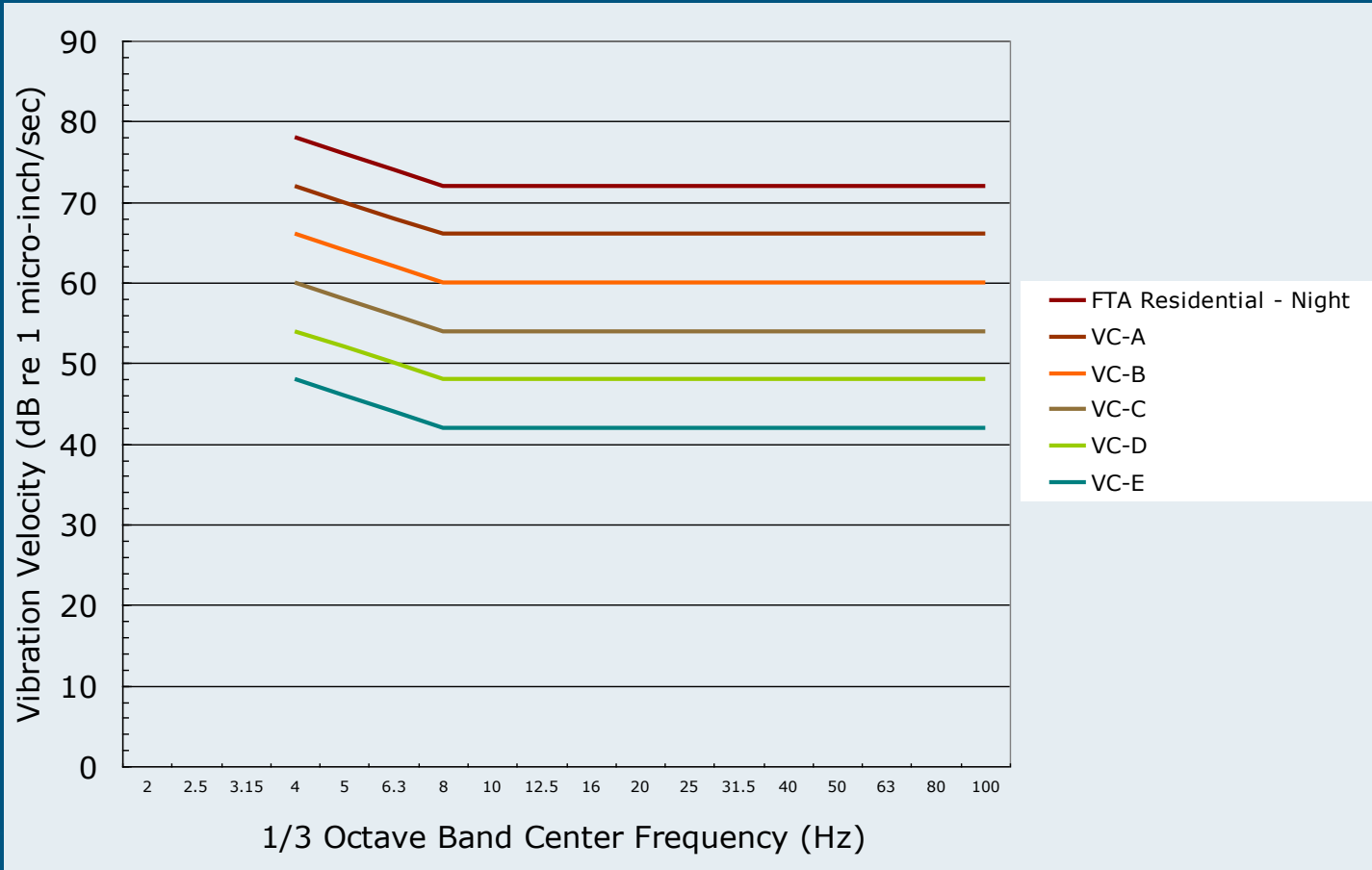
University of Washington

- Premier public university
- Grants exceeding \$1,000,000,000 annually
- Concerned about vibration and EMI
 - Current research
 - Future faculty and grants
- UW and Sound Transit agreement: vibration thresholds based on ambient

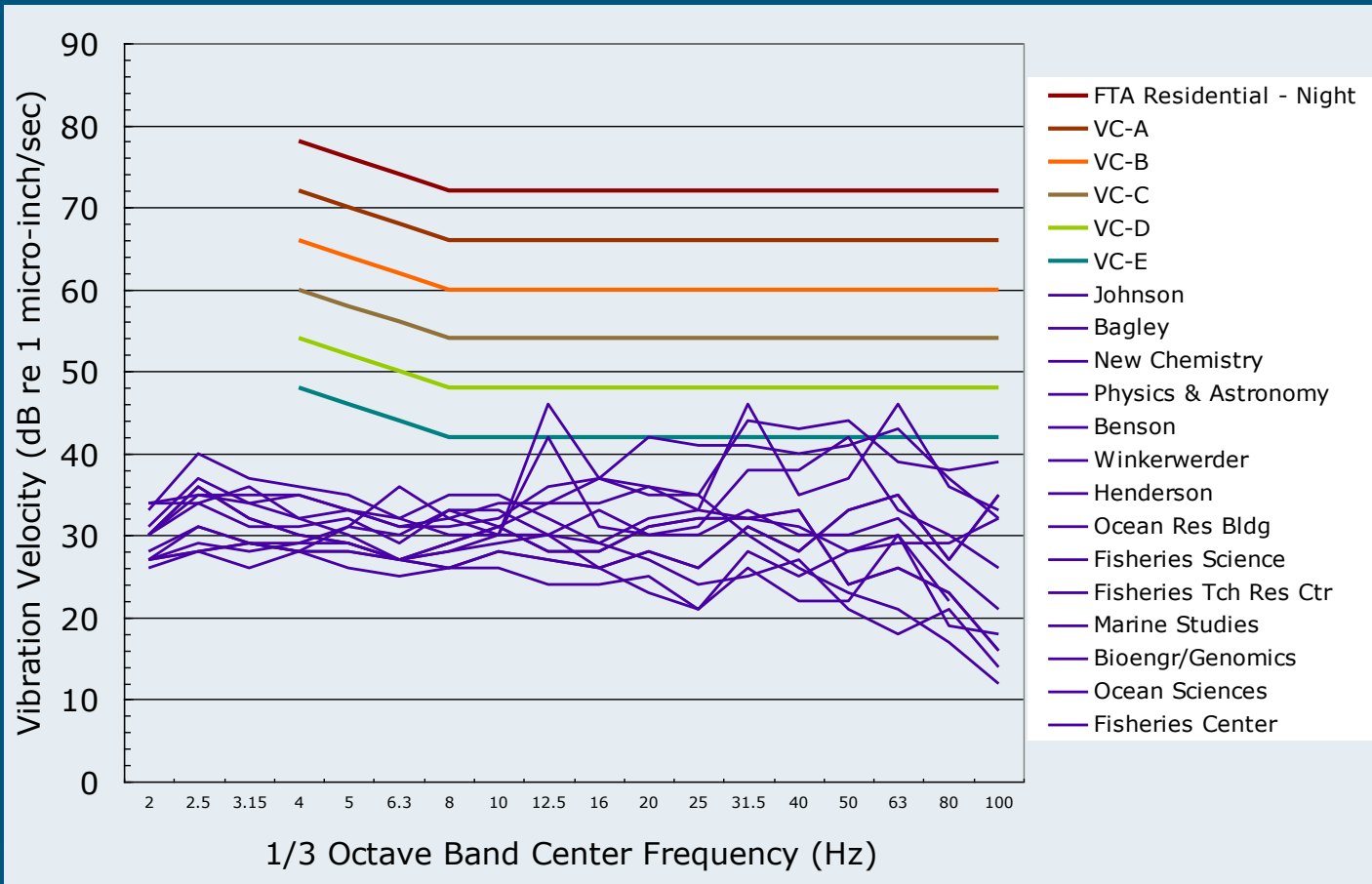
UW Buildings of Concern



FTA Vibration Criteria



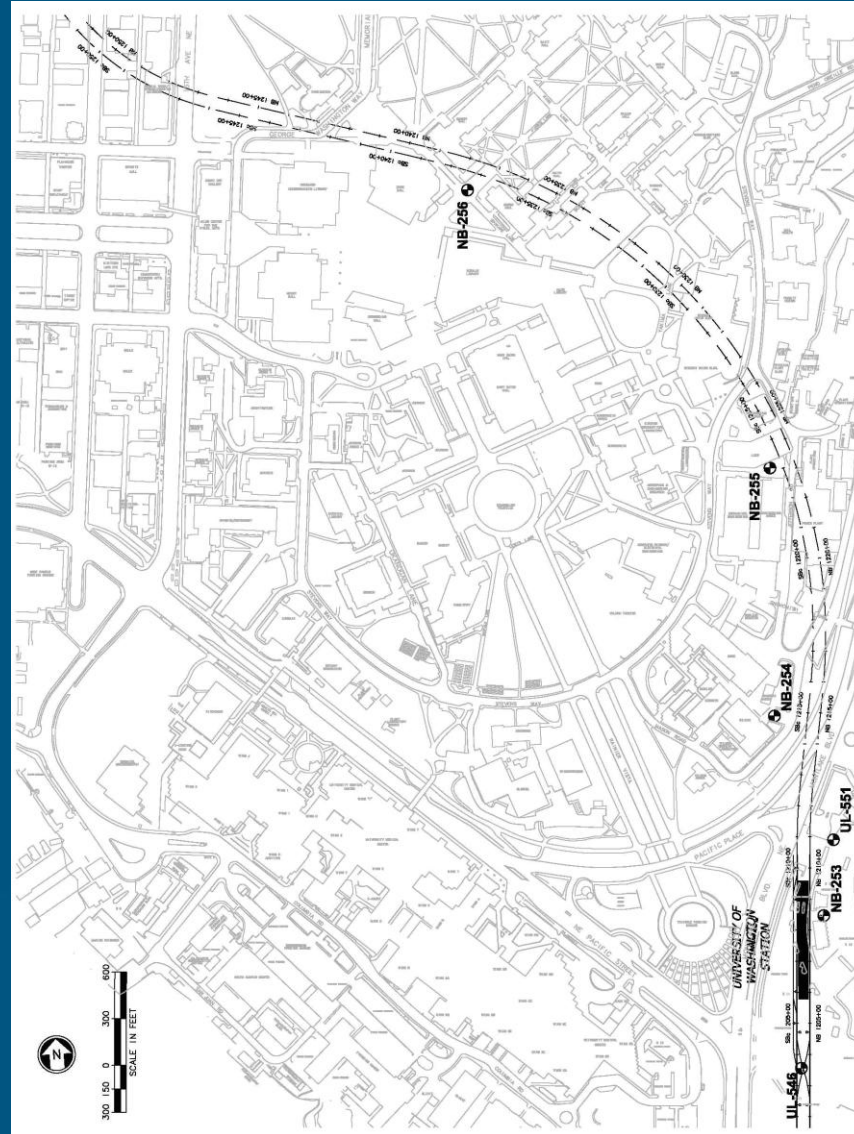
UW Requested Thresholds



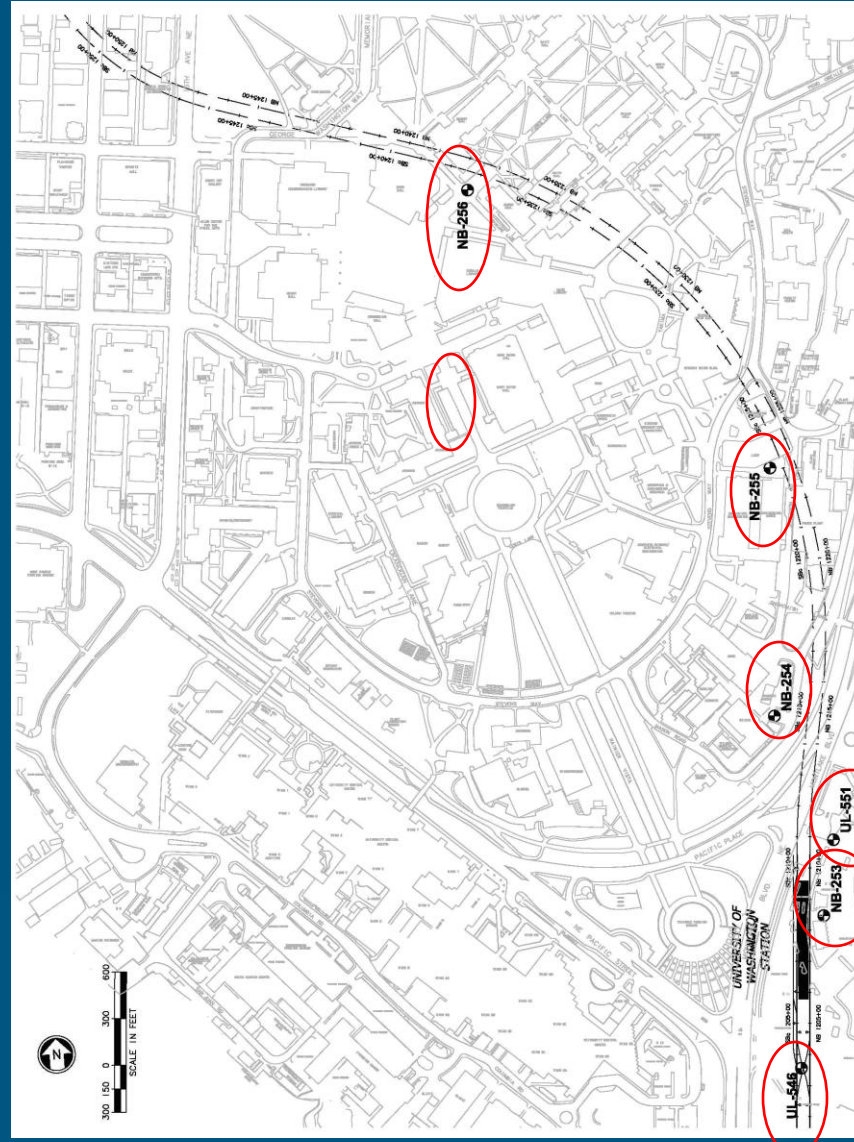
Vibration Prediction

- Vibration = FDL + LSR + BVR
 - FDL = train force density level
 - LSR = soil line source response
 - BVR = building response (zero here)
- FDL tests
 - San Jose (2004)
 - Seattle SODO (2007)
- LSR
 - Empirical data
 - Mathematical modeling

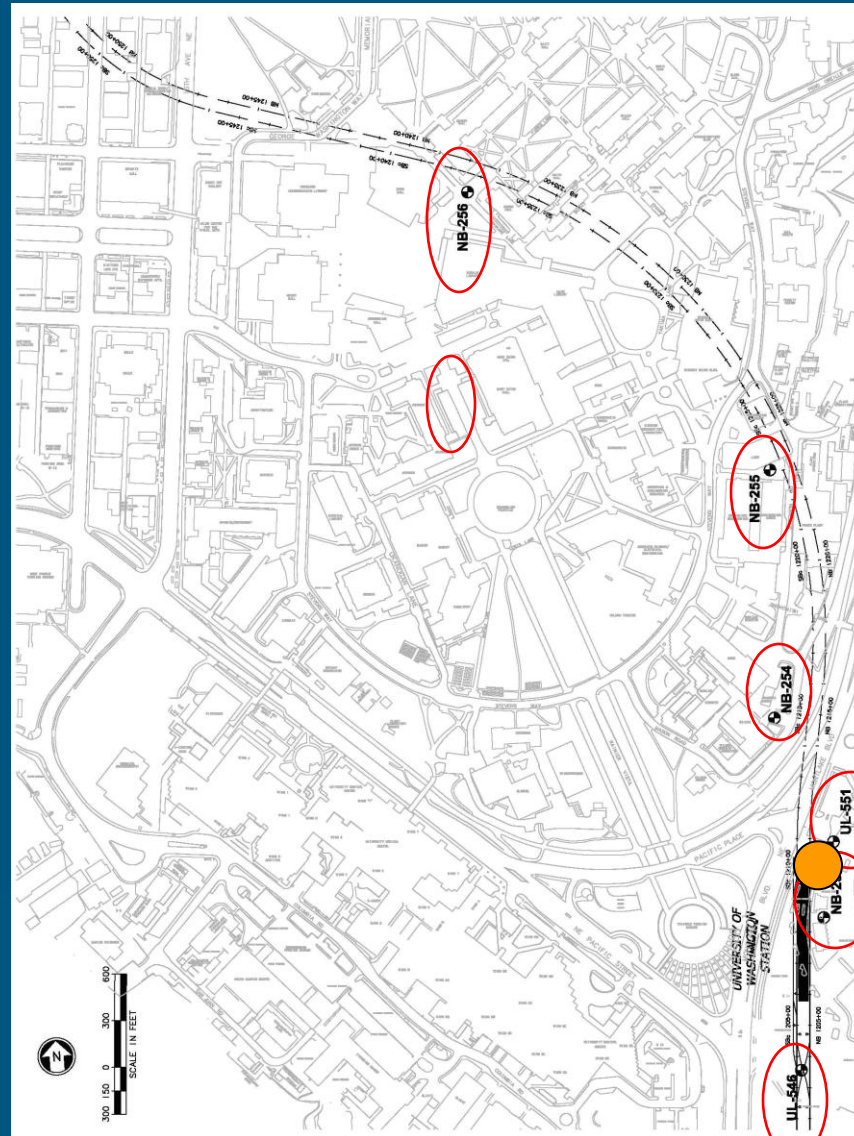
LSR Tests



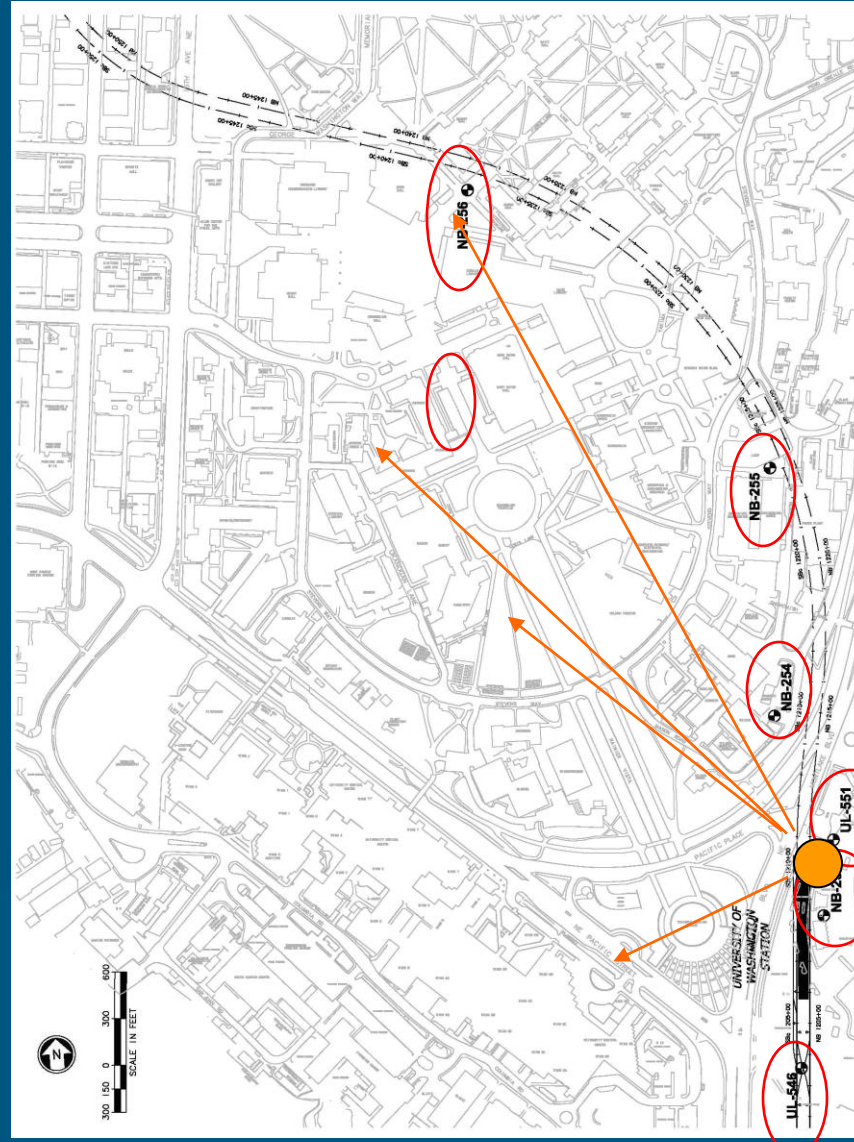
LSR Tests



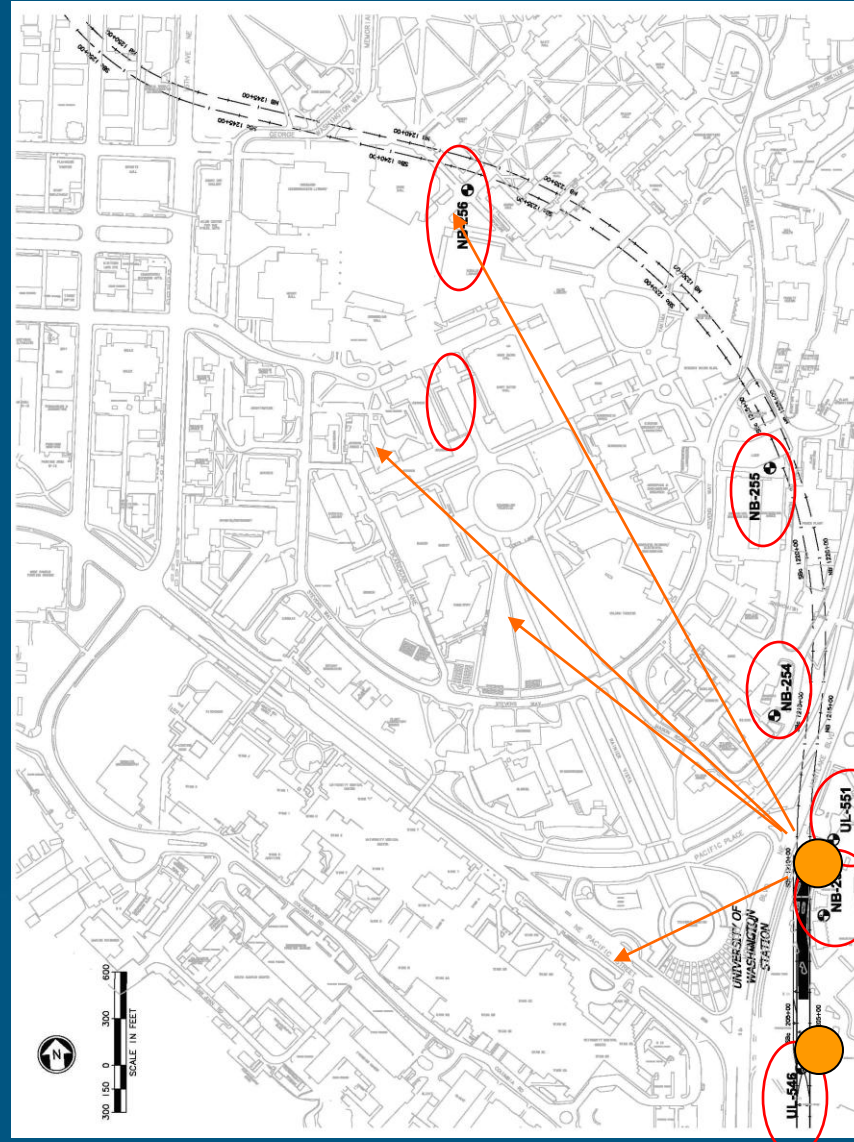
LSR Tests



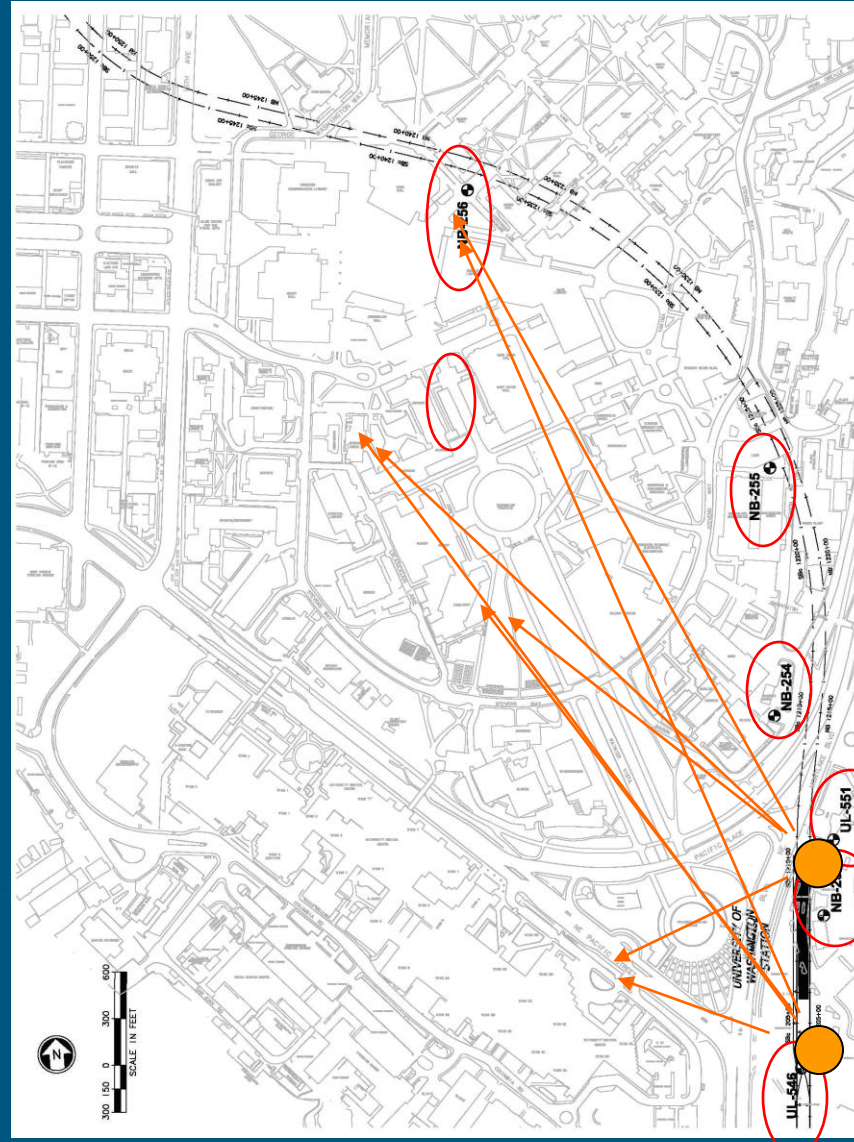
LSR Tests



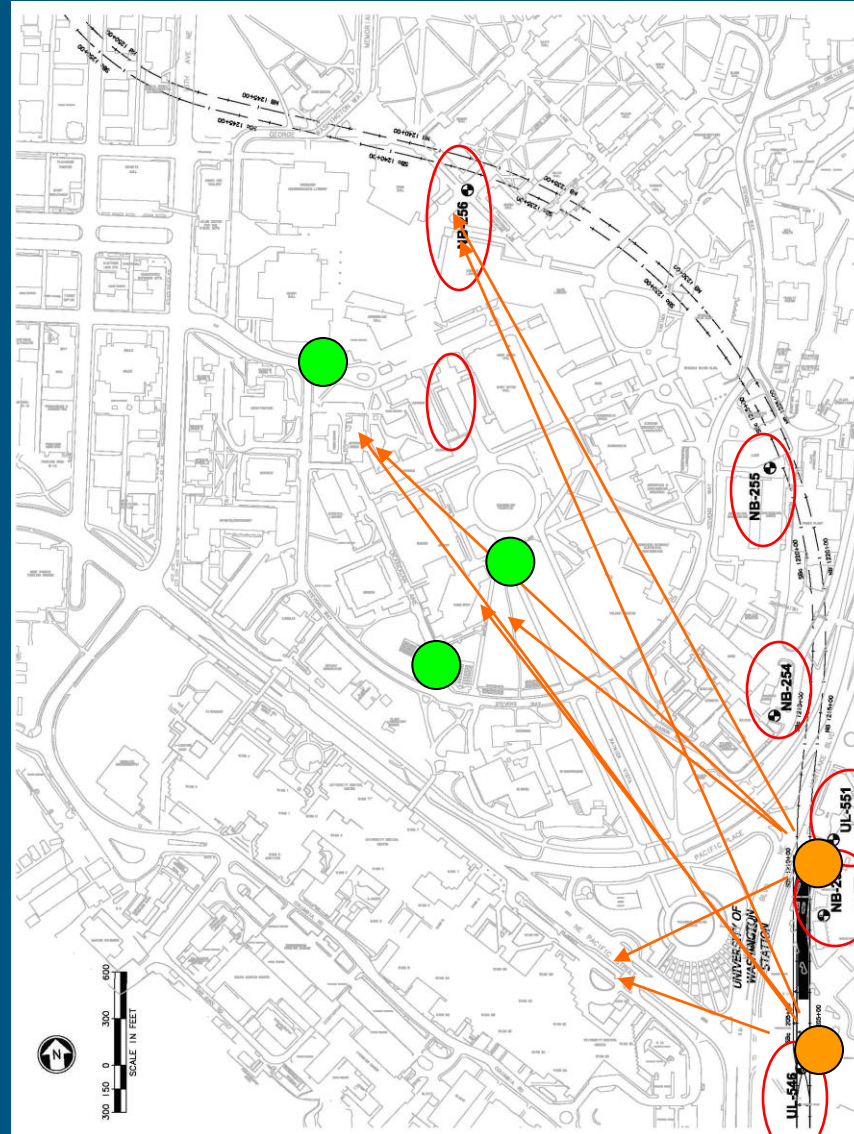
LSR Tests



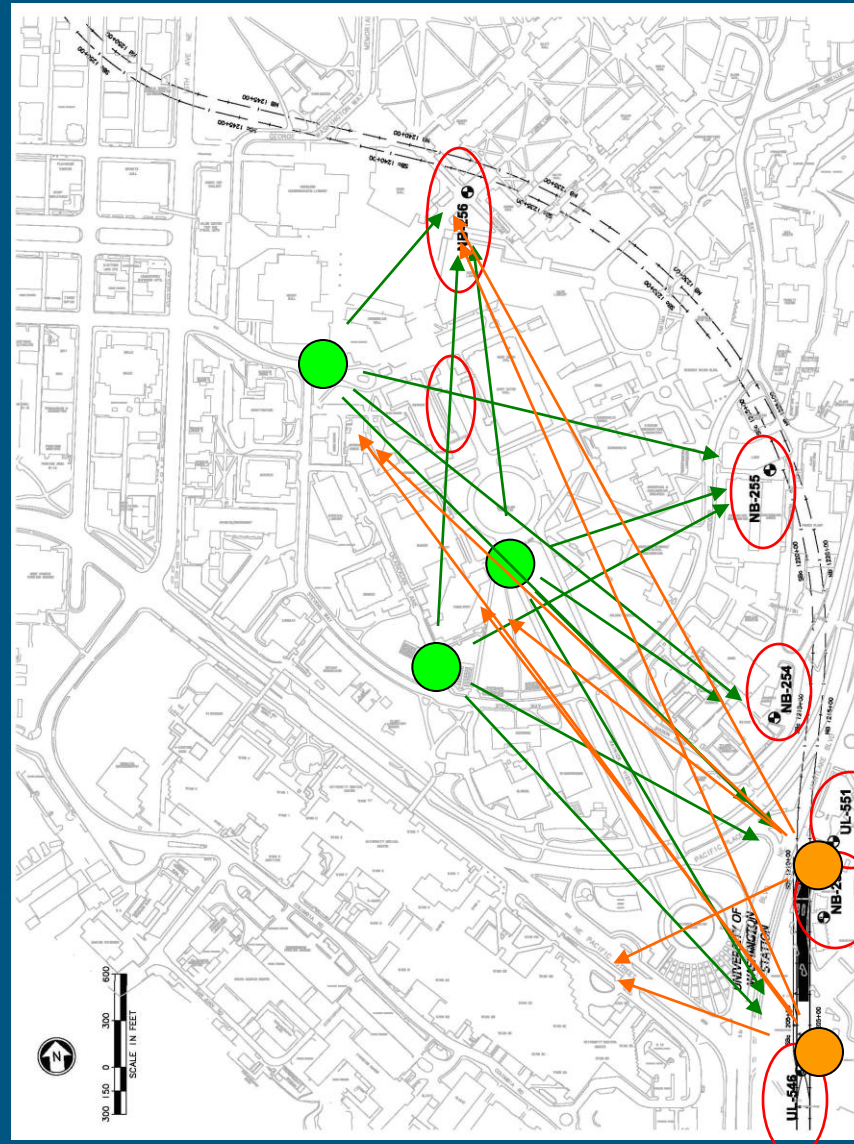
LSR Tests



LSR Tests




LSR Tests



Status at APTA 2009

- Predictions based on mix of modeling and empirical data
- Preliminary vibration control designs
- Uncertainties
 - FDL at low frequencies
 - LSR at long distance and low frequencies
- Unknown influence of rail straightness

Testing at Beacon Hill in 2009

- Train vibration at distance
Closer and closer to UW conditions
- LSR  FDL in tunnel
- Rail Straightness

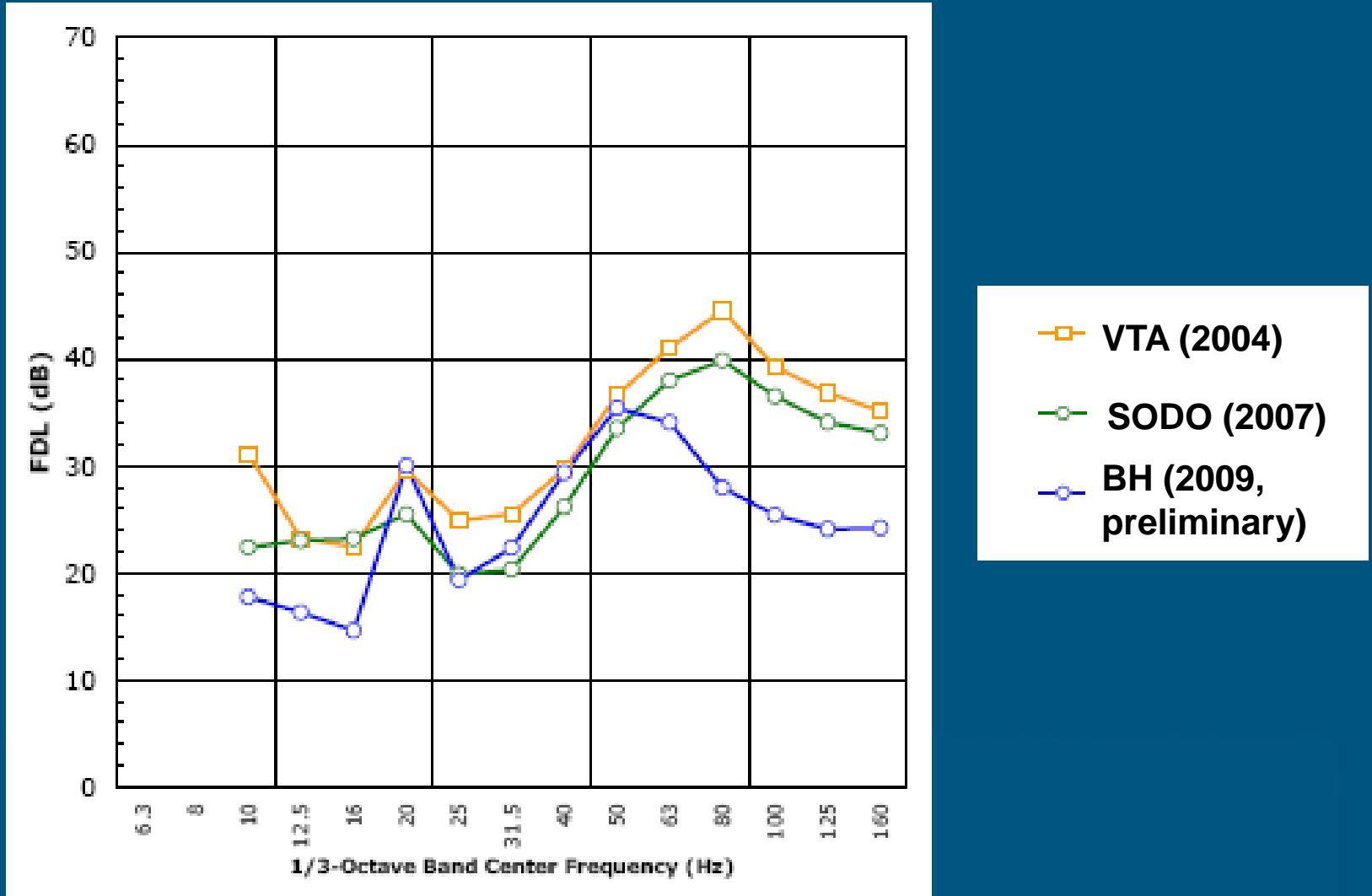
Train Vibration at Distance



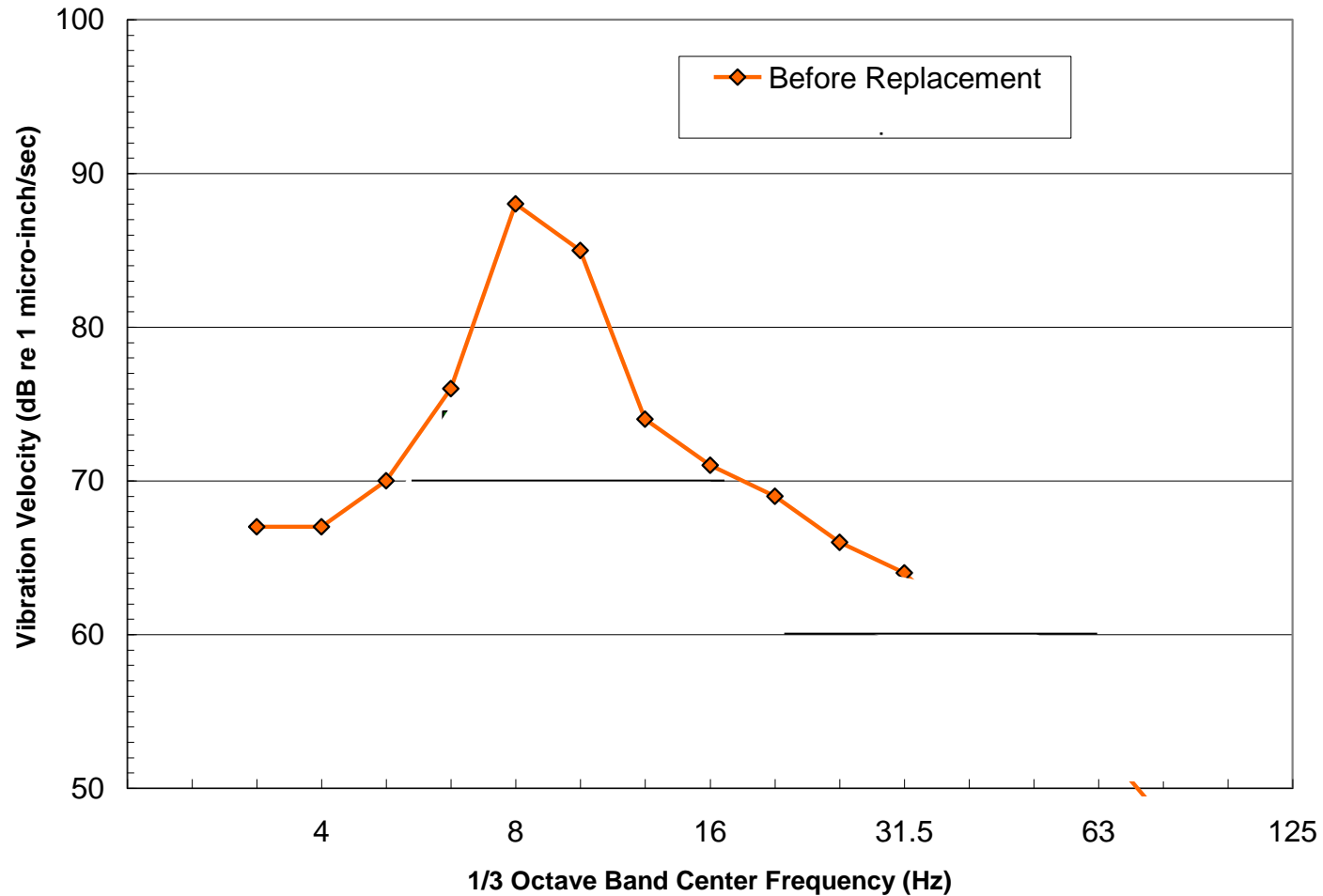
Train Vibration on Beacon Hill

- Difficult to detect vibration below 8 Hz beyond 400 ft
- Vibration at 20 Hz and higher detectable out to at least 800 ft
- Primary suspension resonance at 10 Hz evident out to 800 ft
- Unexpected peak around 20 Hz seen out to 800 ft

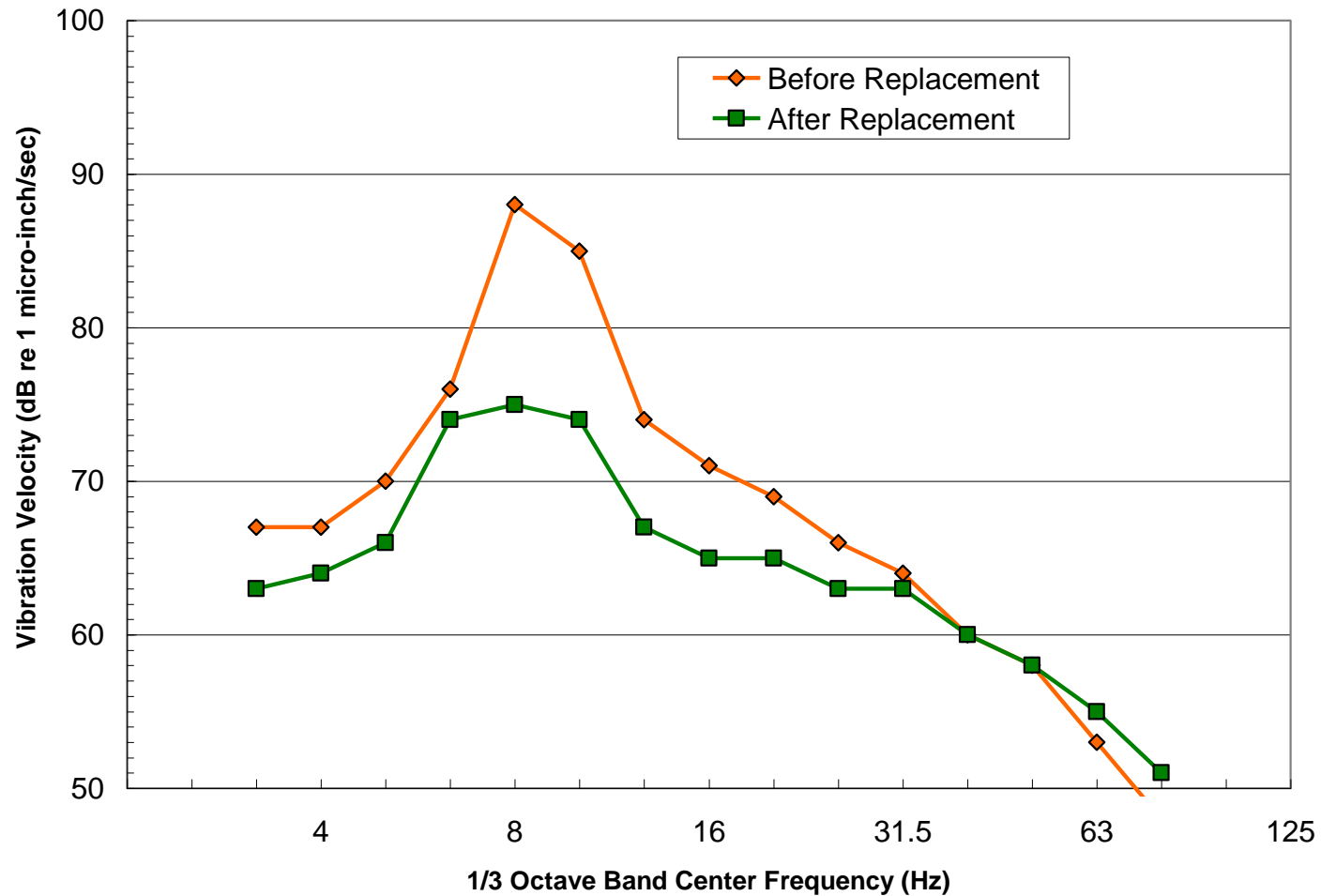
FDL Development



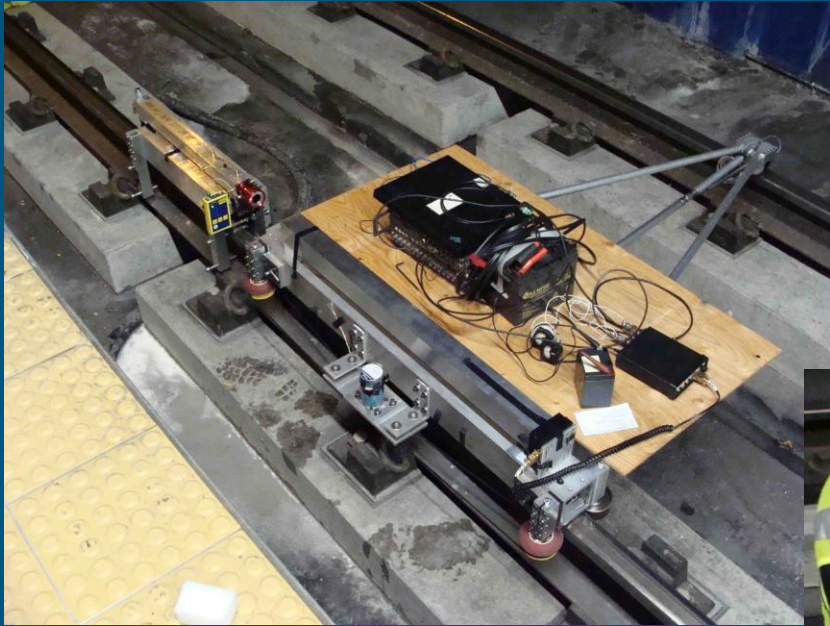
Rail Undulation At CNRail Kamloops



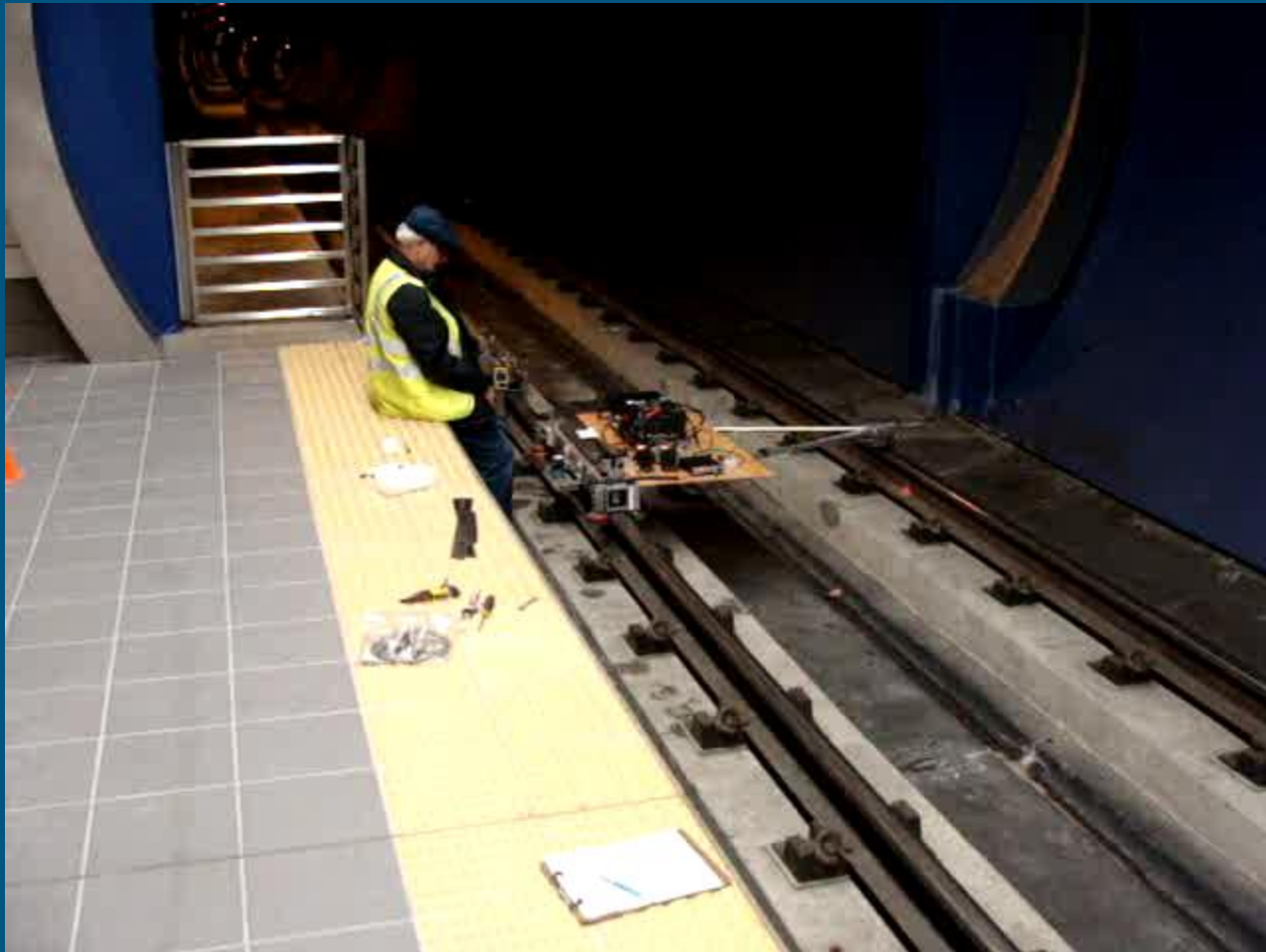
Rail Undulation At CNRail Kamloops



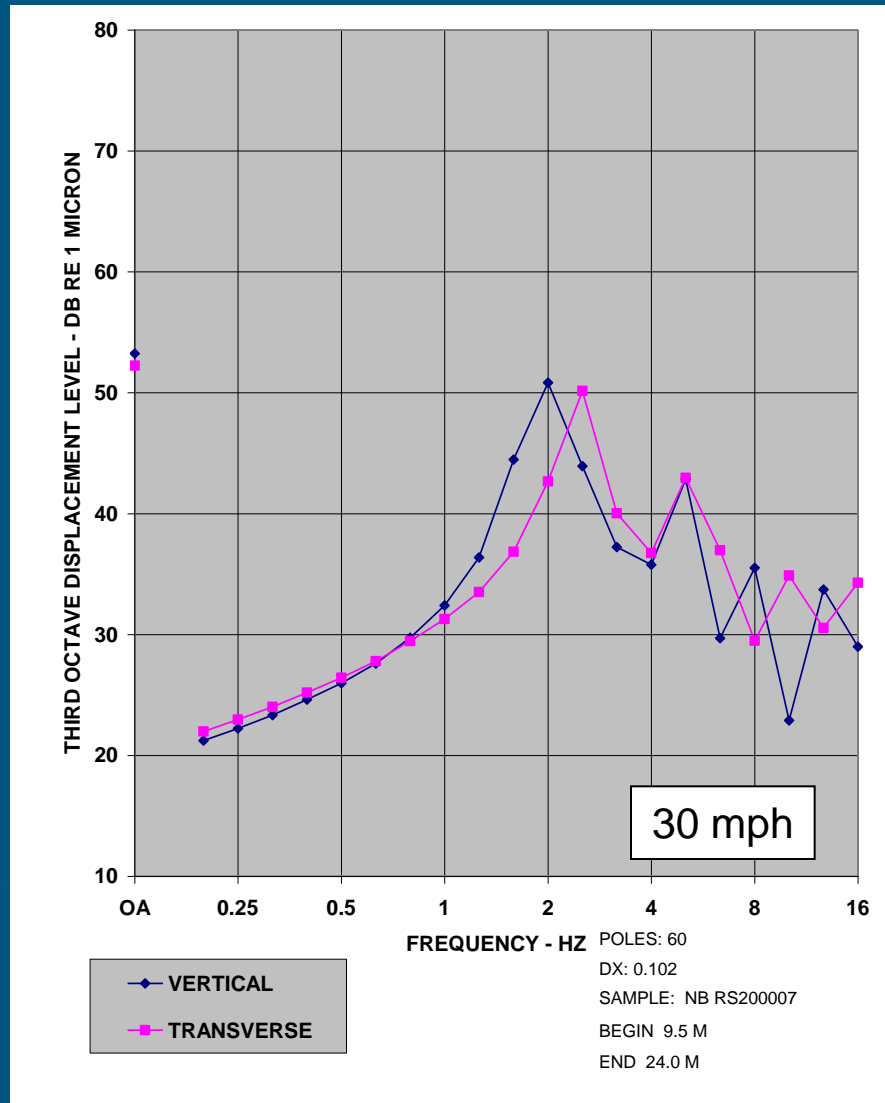
Rail Straightness Test Rig



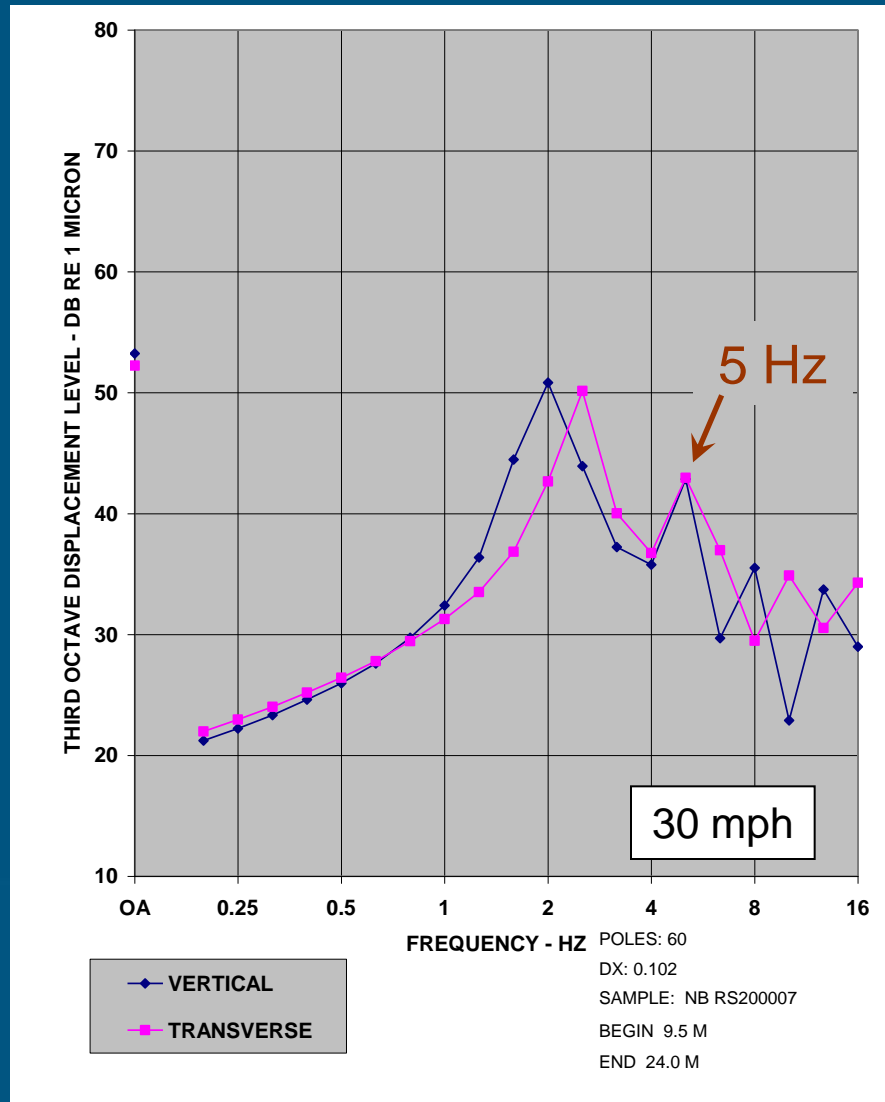
Rail Straightness Measurement



Rail Straightness Result



Rail Straightness Result



Vibration Control Measures

- Relocate alignment (already done)
- Track Vibration Isolation
- High Compliance DF Fasteners
- Rail Straightness Specification
- Moveable Point Frogs
- Flange Bearing Crossing Diamond
- Wheel Flat Detection
- Speed Reduction (as needed)
- Laboratory Relocation (if needed)
- Vibration Monitoring System

Where Are We Now?

- University Link
 - Preparing bid documents for trackwork and prototype floating slab
 - Vibration measurements expected 2016
- North Link
 - Final design begins in September
 - Track isolation design to be finished
 - Rail straightness spec being evaluated

Take Aways

- At universities and other special locations, you have to go beyond standard FTA methods
- Unusually low thresholds will require a mix of non-standard solutions
- Tests and methods to deal with long range and low frequency vibration are being developed, but still much uncertainty