

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

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2010 RAIL CONFERENCE

Sound Transit North Link

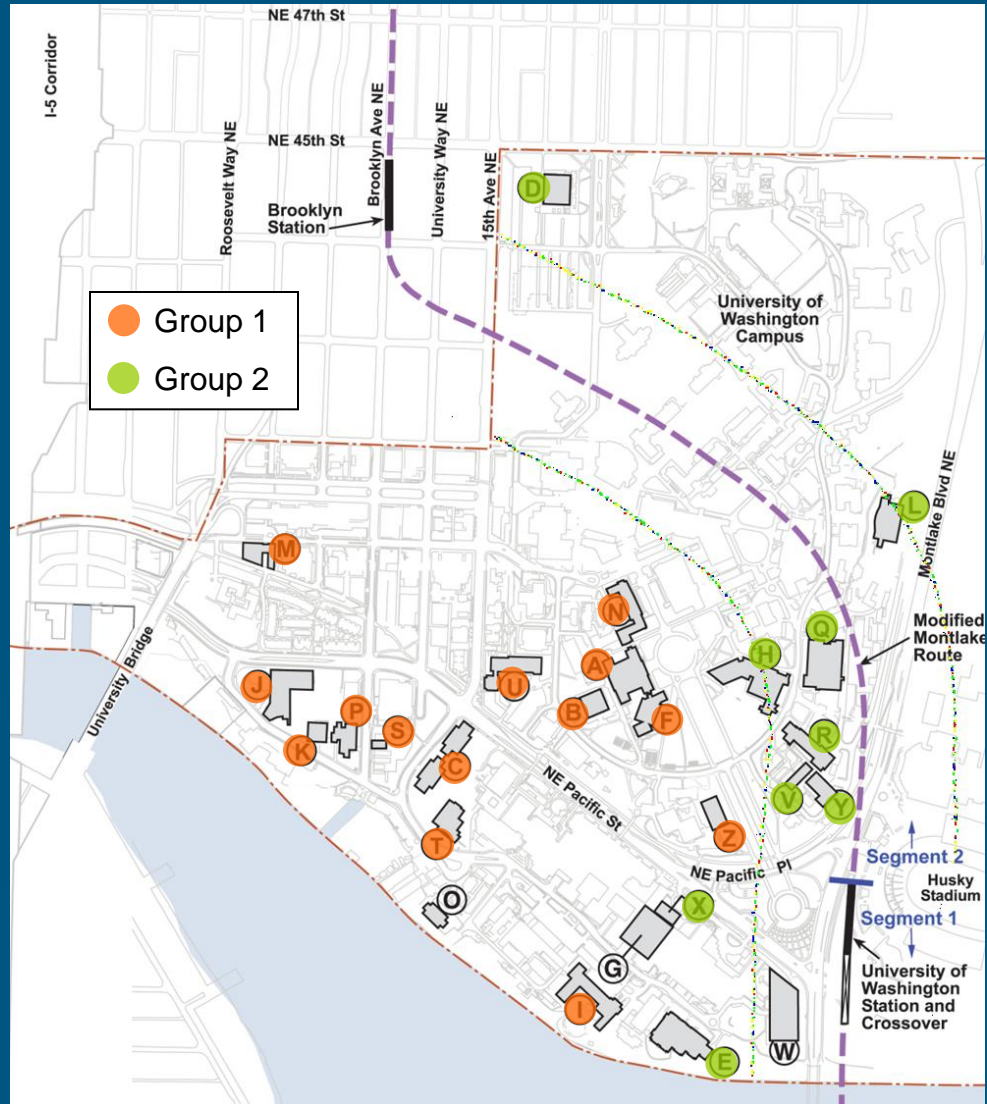
- Extends subway from downtown Seattle
 - 6.5 miles in tunnel
 - 1 mile at-grade/aerial
 - U-Link / North Link
- Revenue service
 - U-Link: 2016
 - North Link: 2020



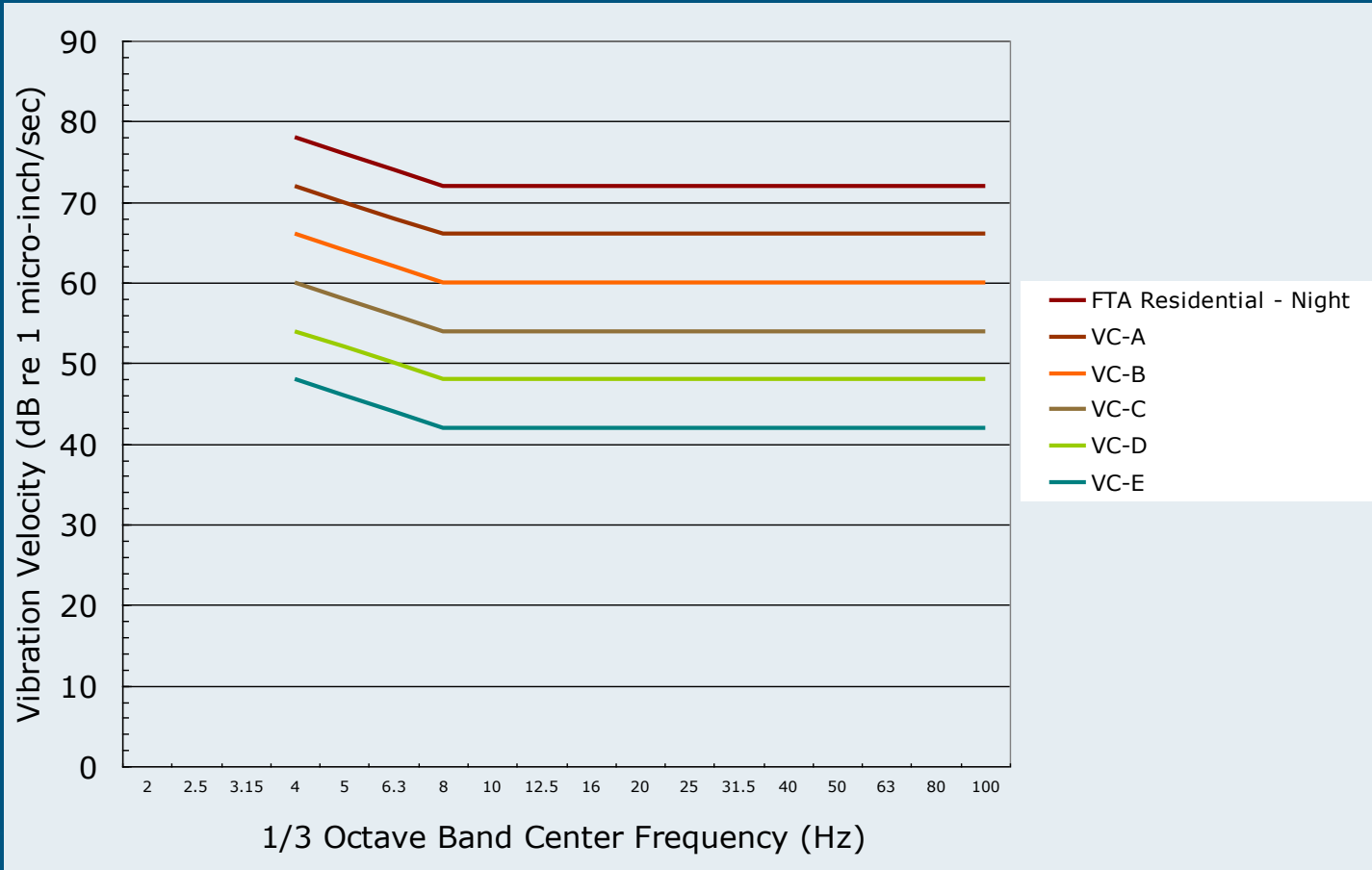
University of Washington

- 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

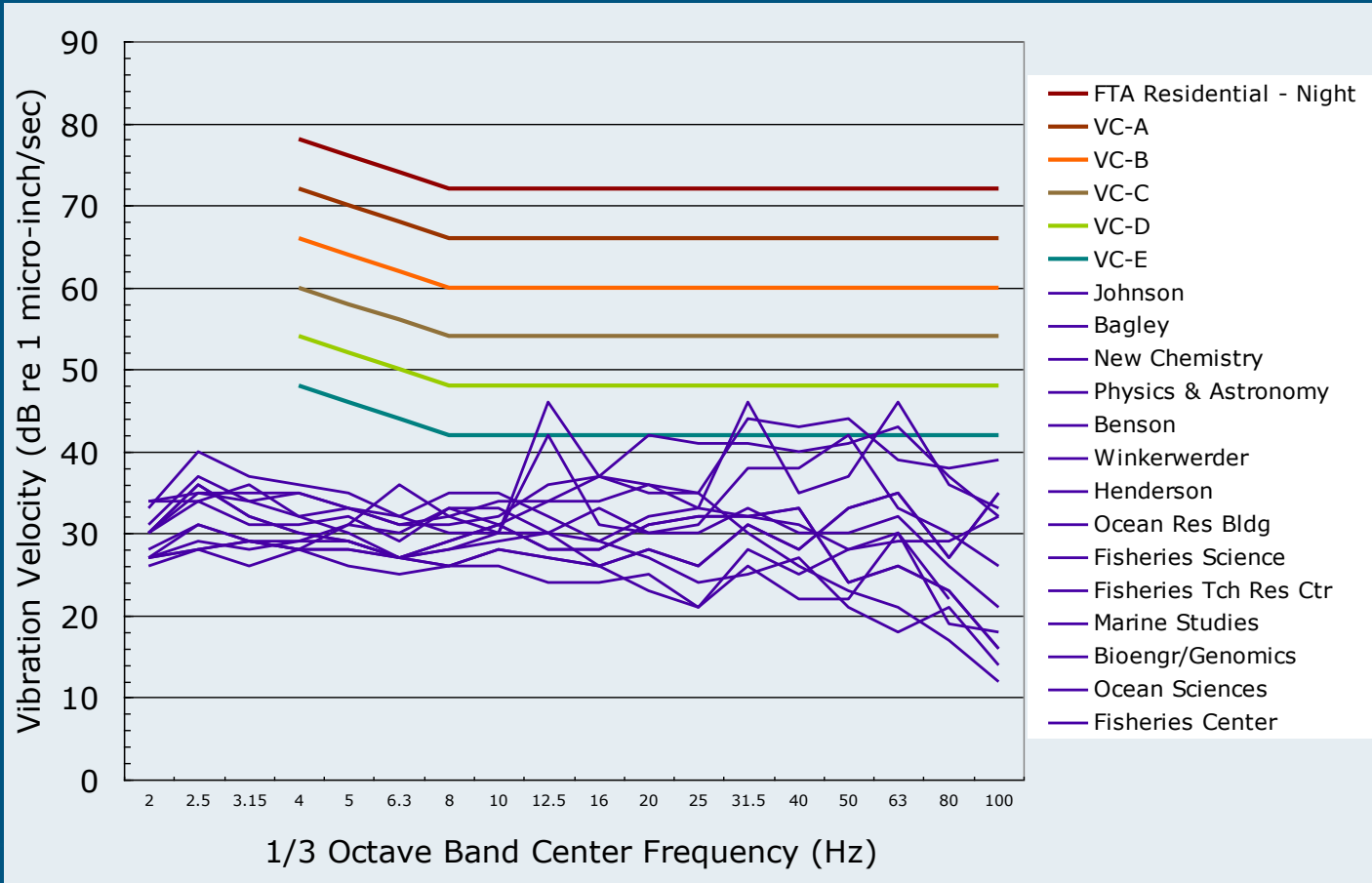
UW Buildings of Concern



FTA Vibration Criteria



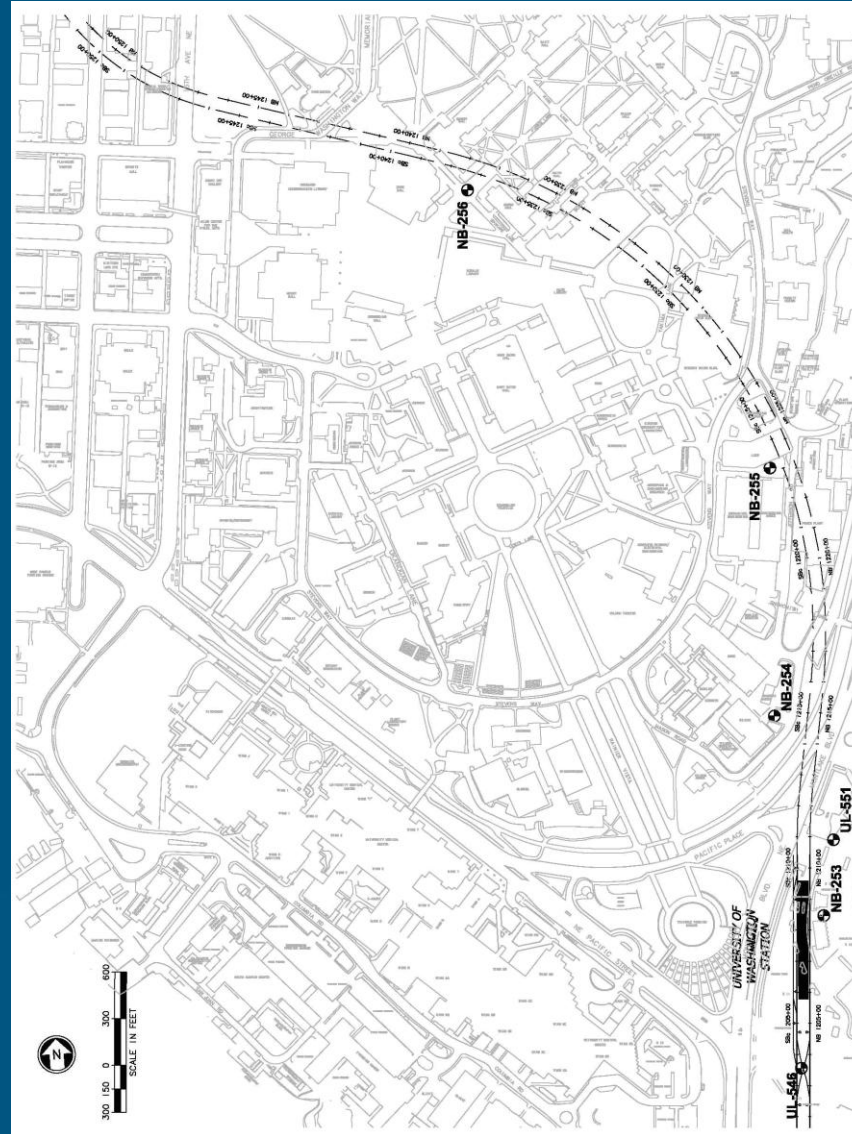
UW Requested Thresholds



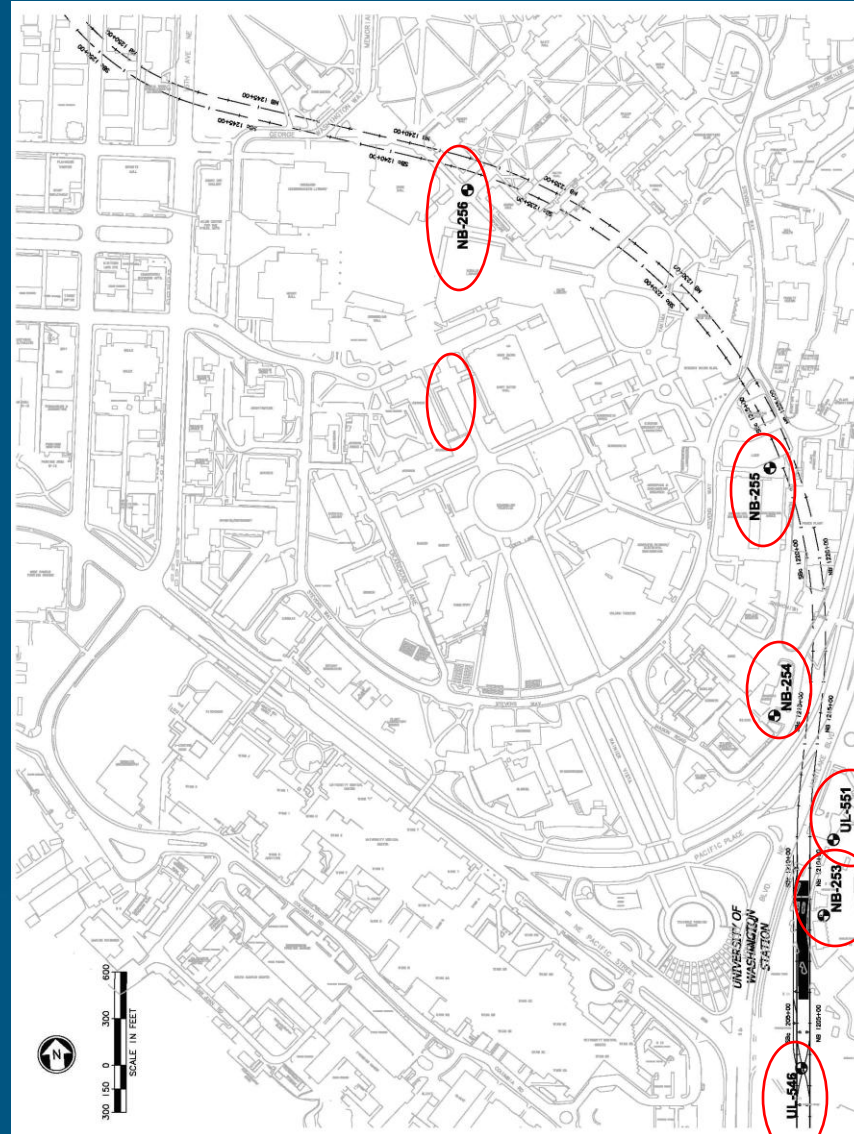
Vibration Prediction

- 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

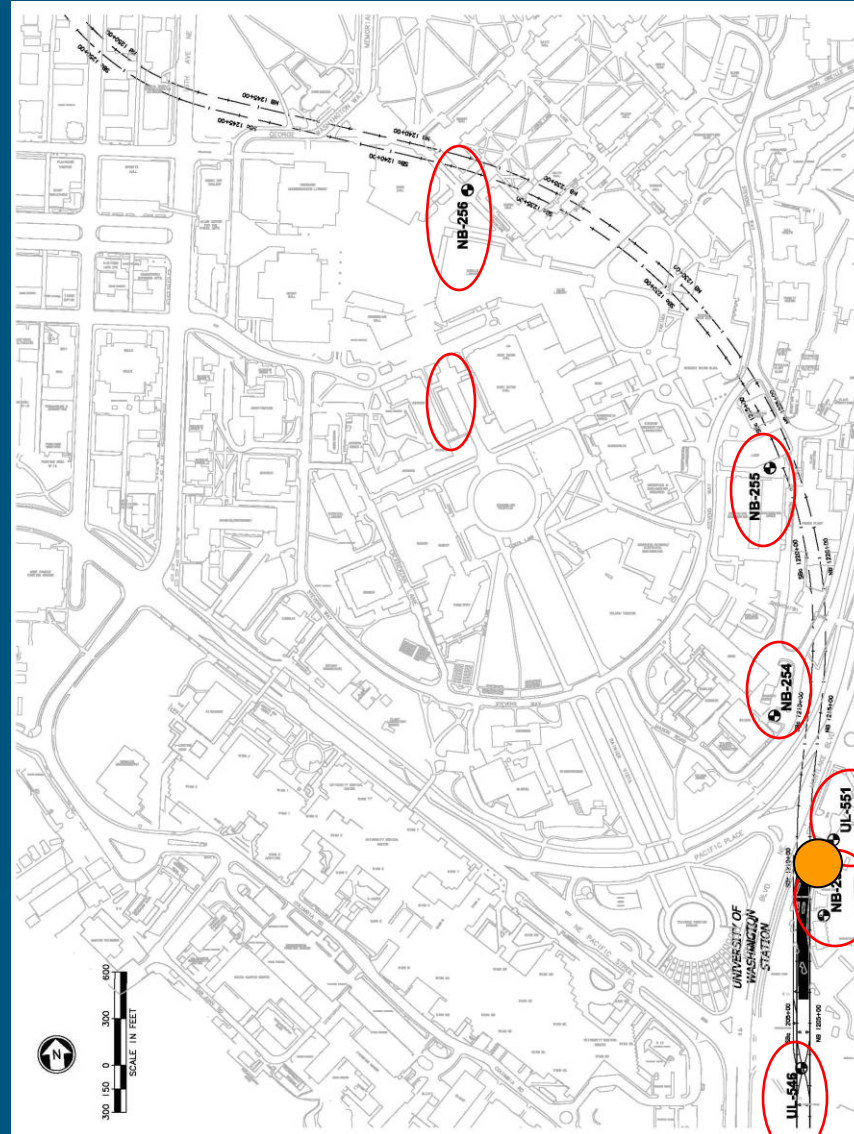
LSR Tests



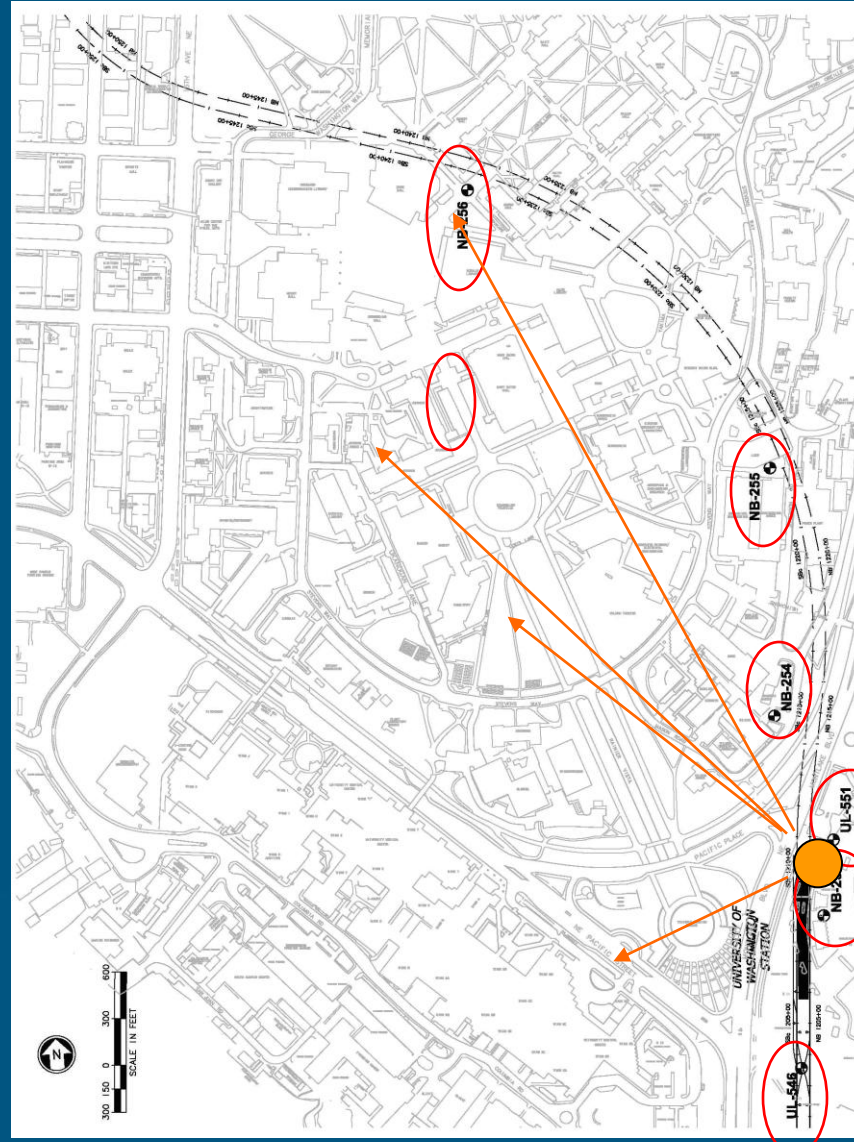
LSR Tests



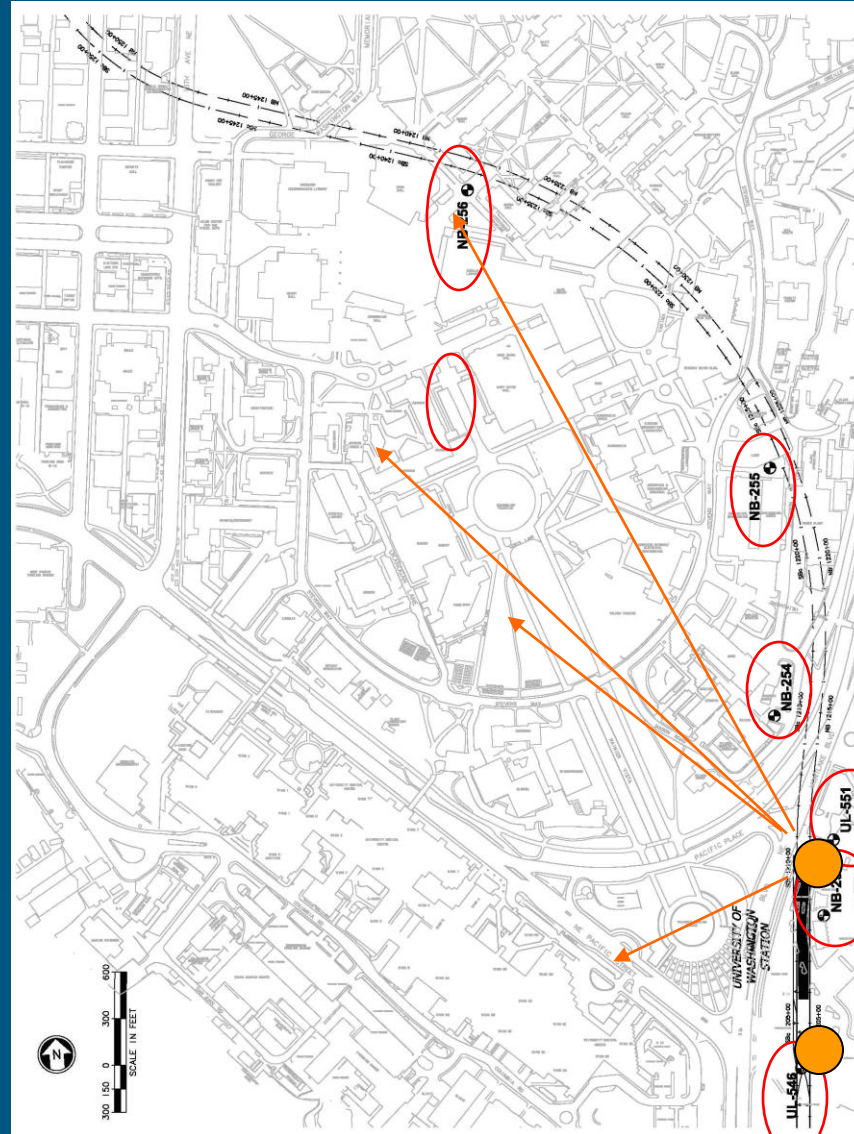
LSR Tests



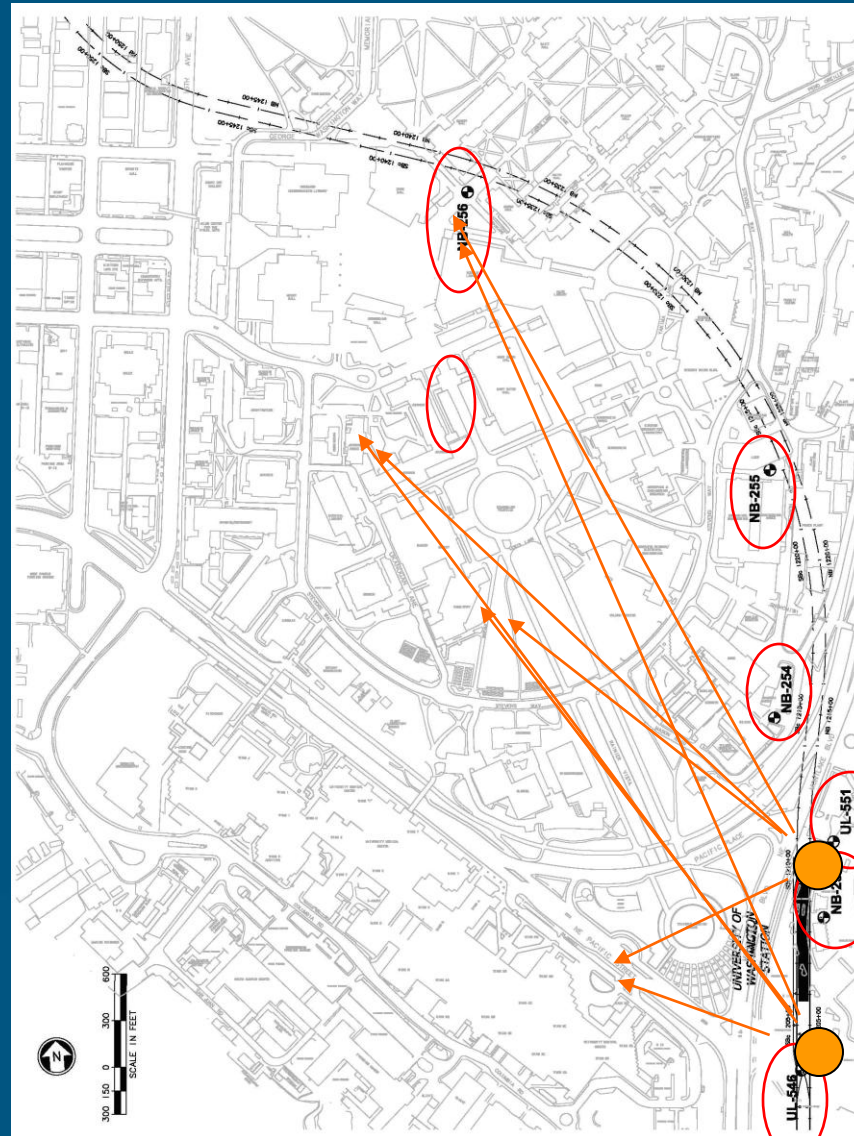
LSR Tests



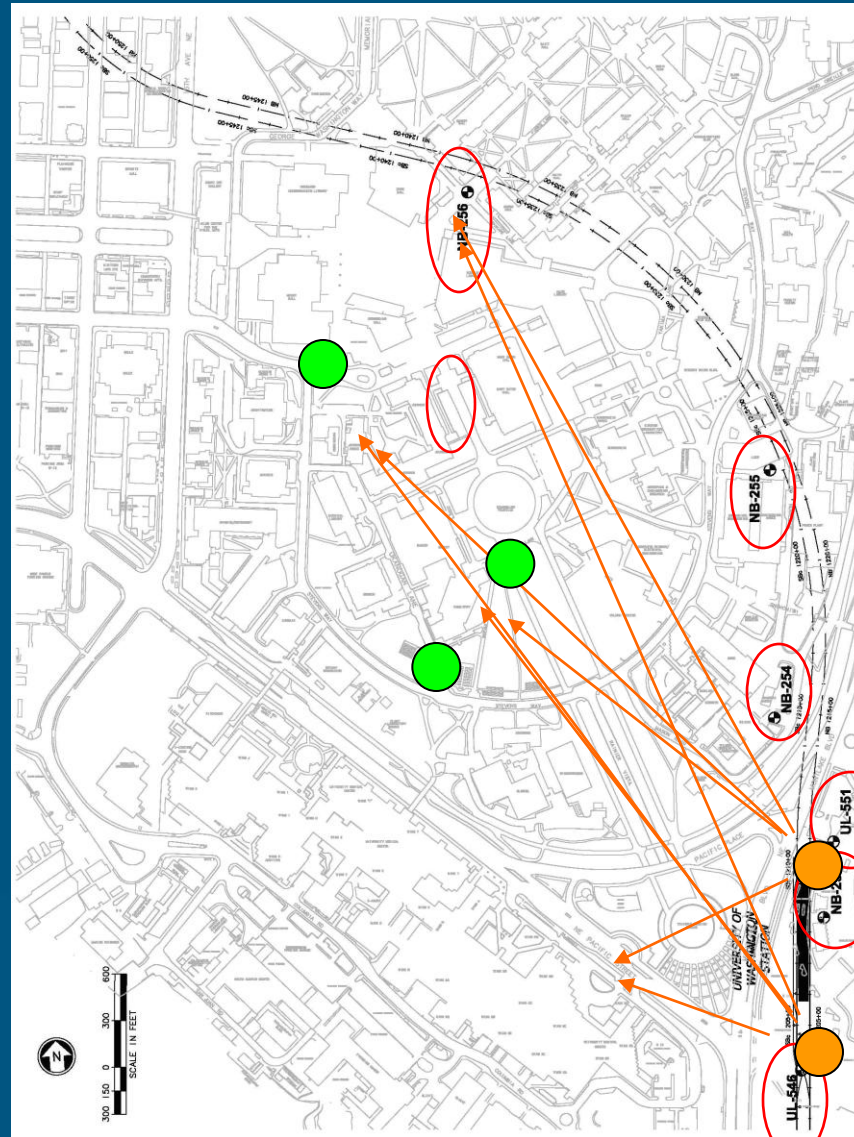
LSR Tests



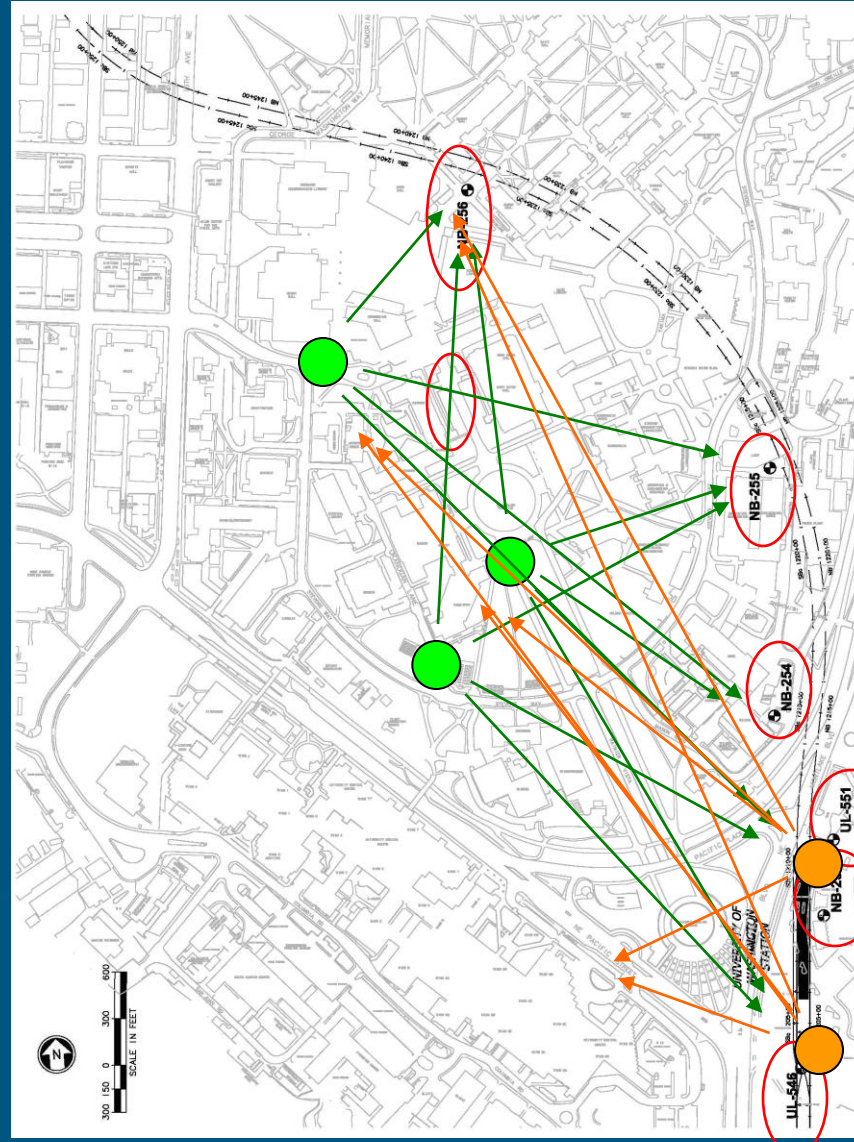
LSR Tests



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

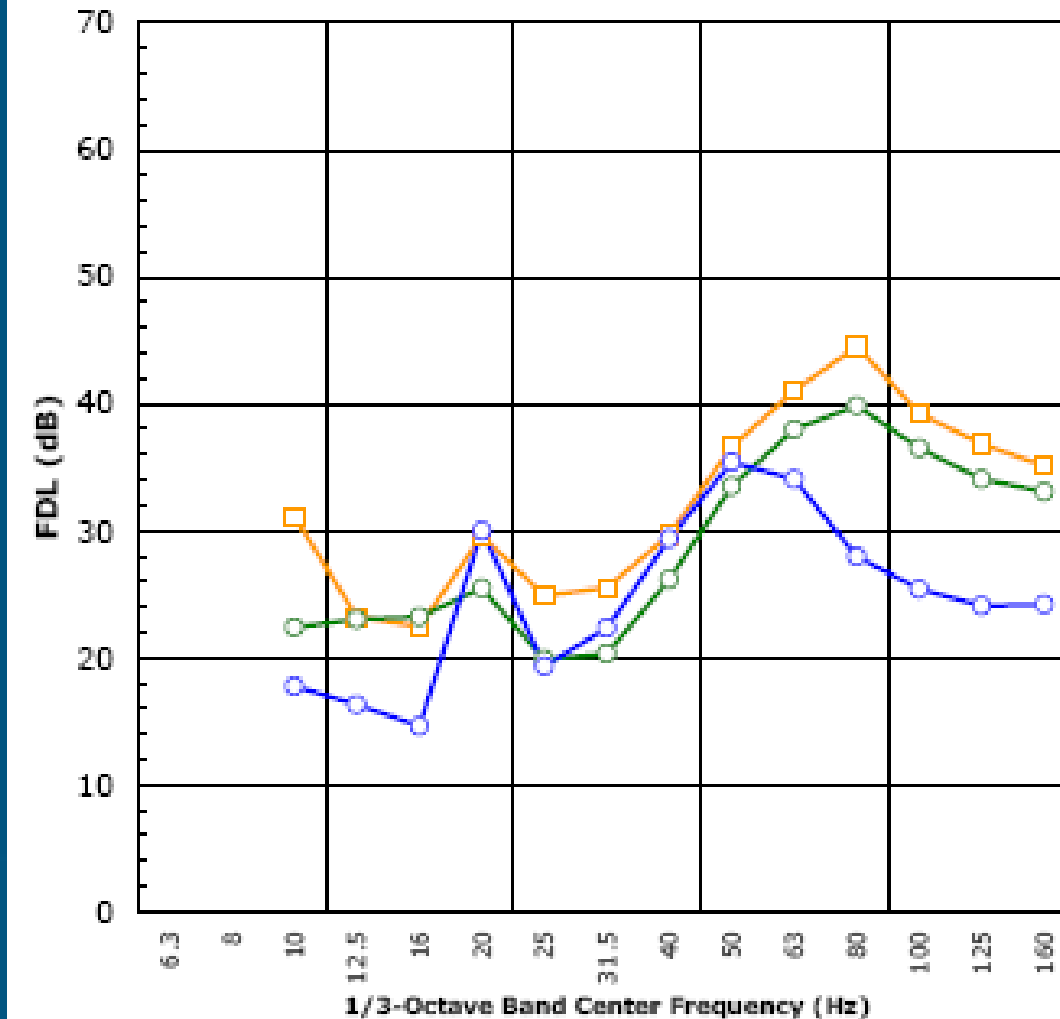
Train Vibration at Distance



Train Vibration on Beacon Hill

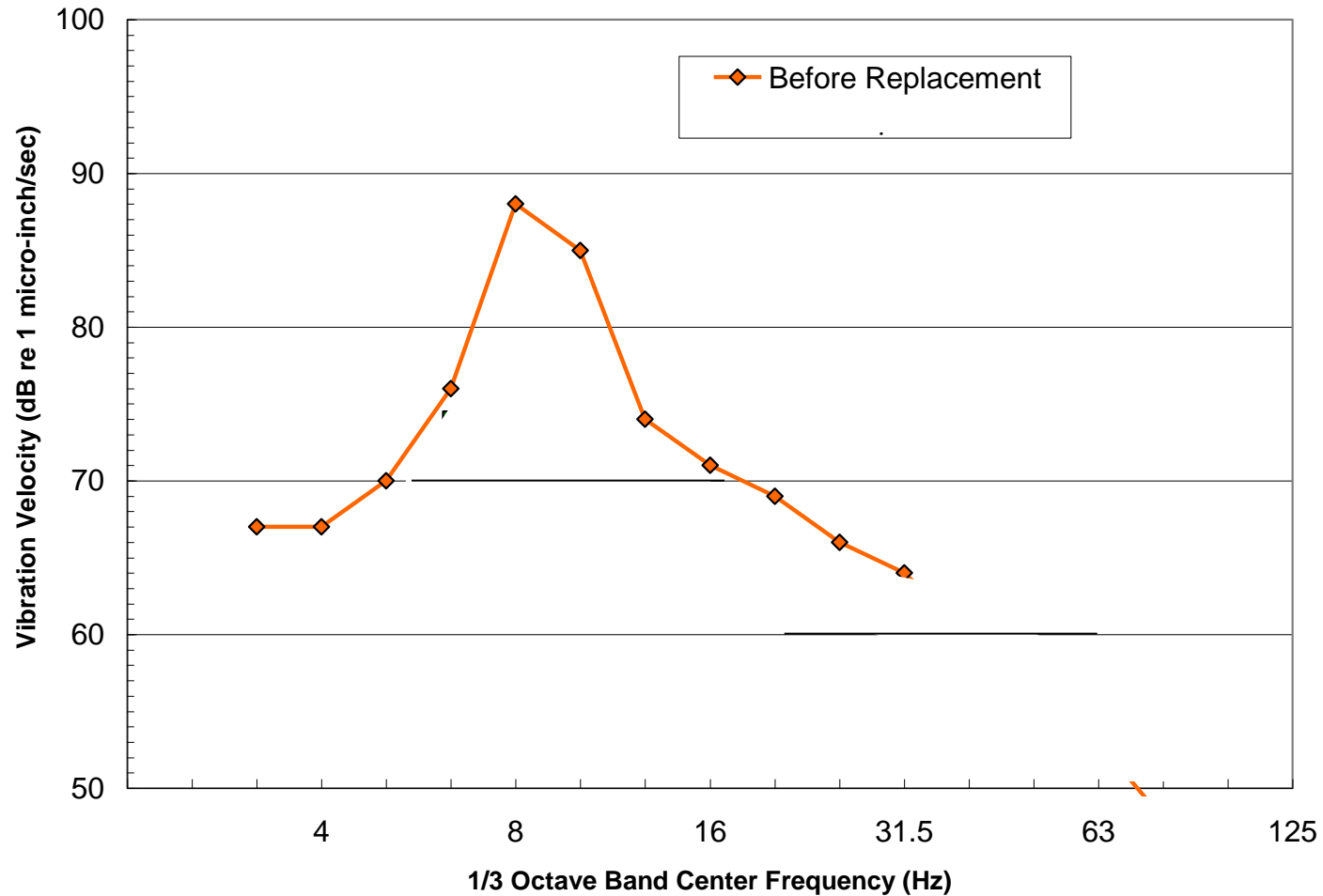
- Difficult to detect vibration below 8 Hz beyond 400 ft
- Vibration at 20 Hz and higher detectable out to at least 800 ft
- Primary suspension resonance at 10 Hz evident out to 800 ft
- Unexpected peak around 20 Hz seen out to 800 ft

FDL Development

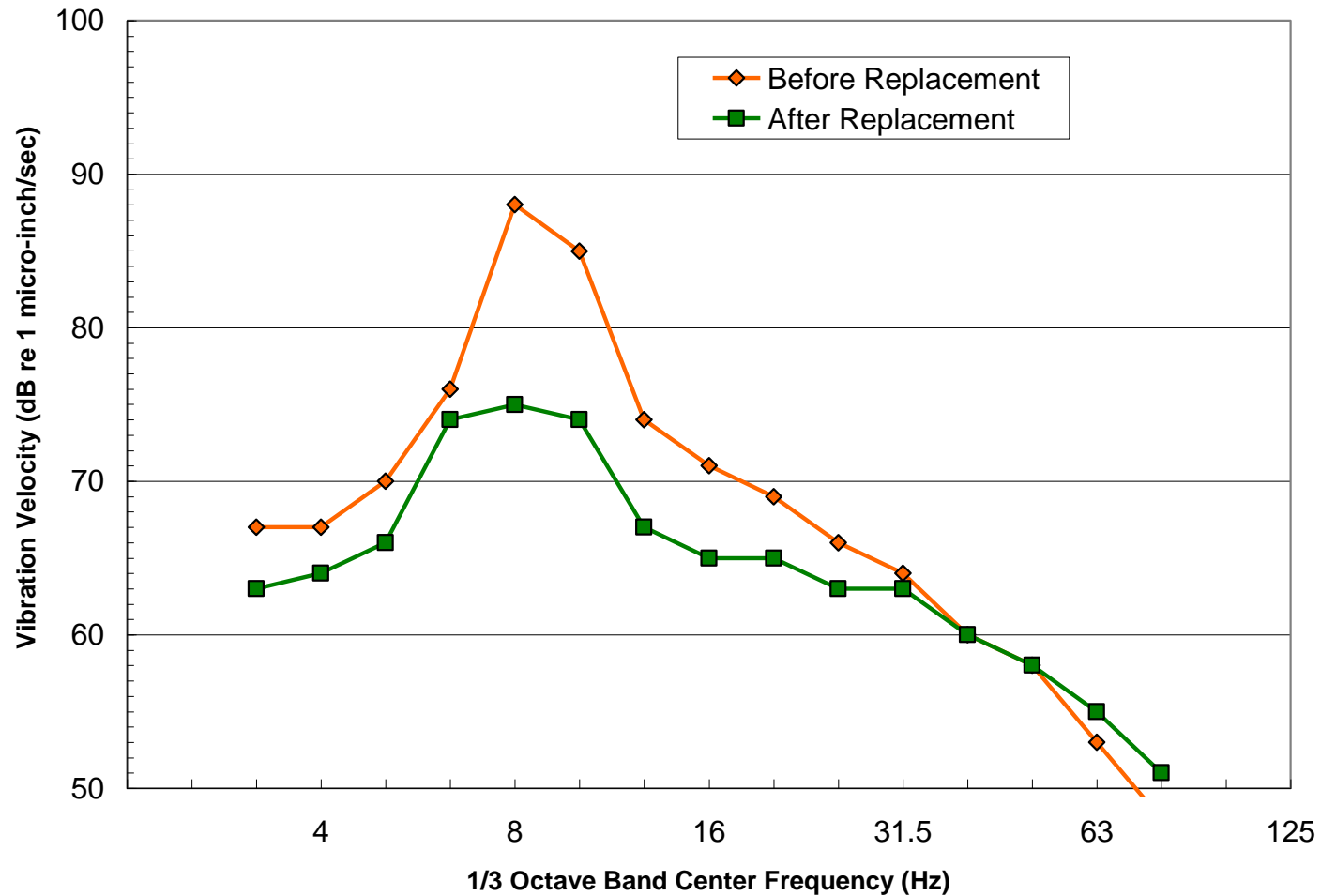


- VTA (2004)
- SODO (2007)
- BH (2009, preliminary)

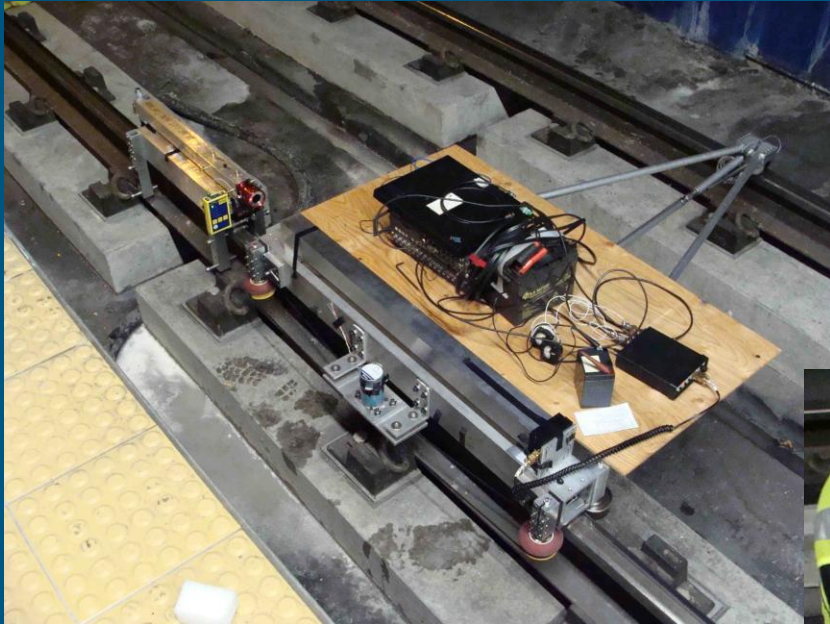
Rail Undulation At CNRail Kamloops



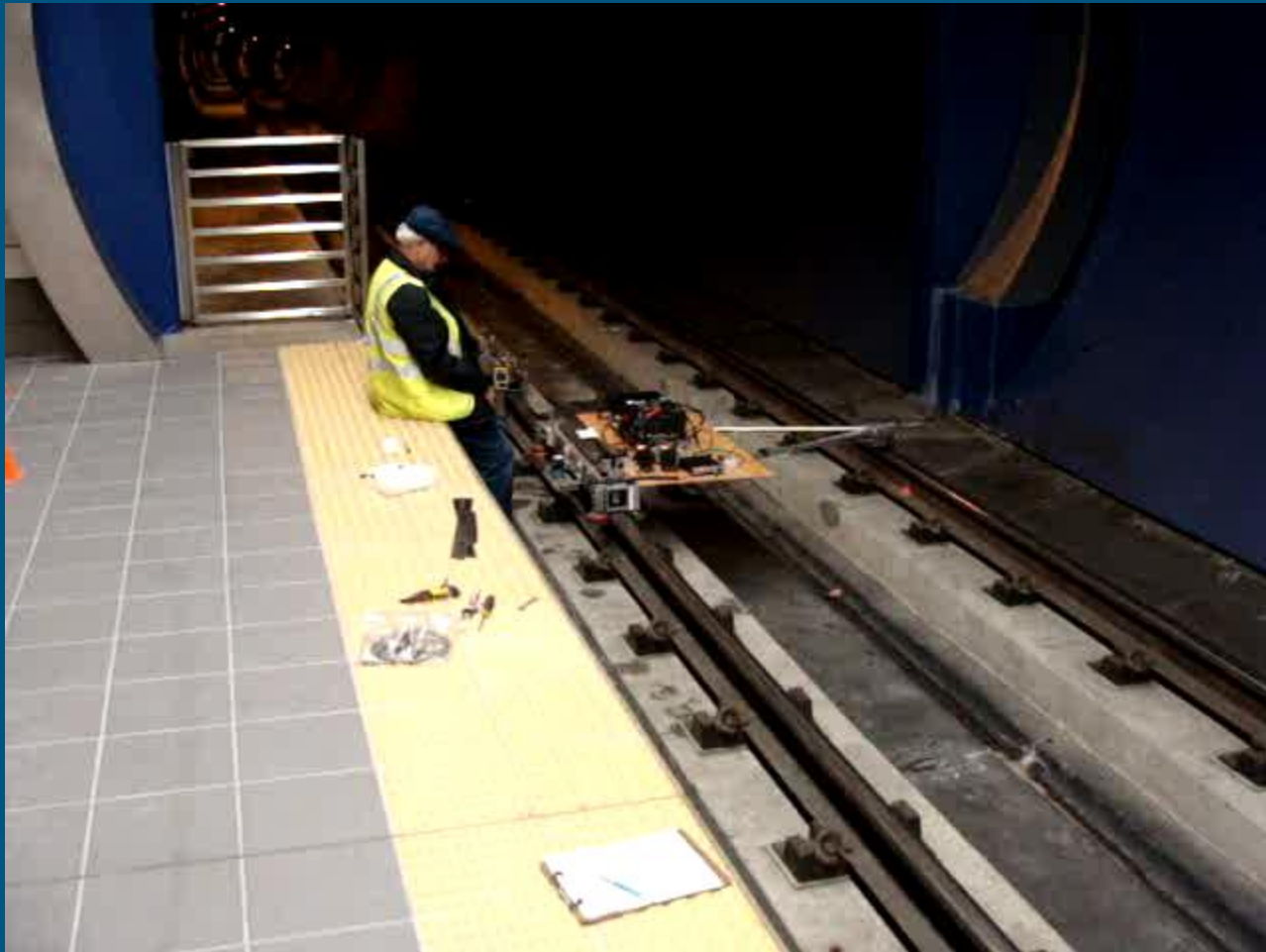
Rail Undulation At CNRail Kamloops



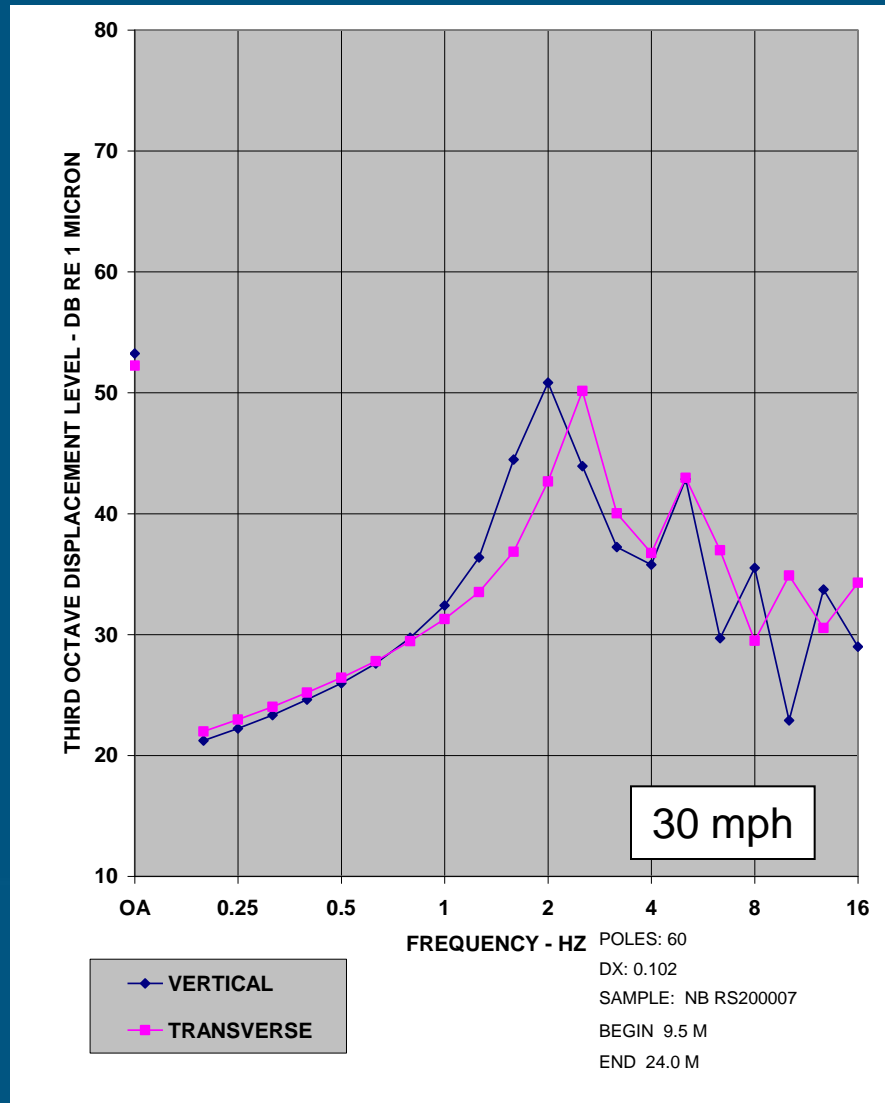
Rail Straightness Test Rig



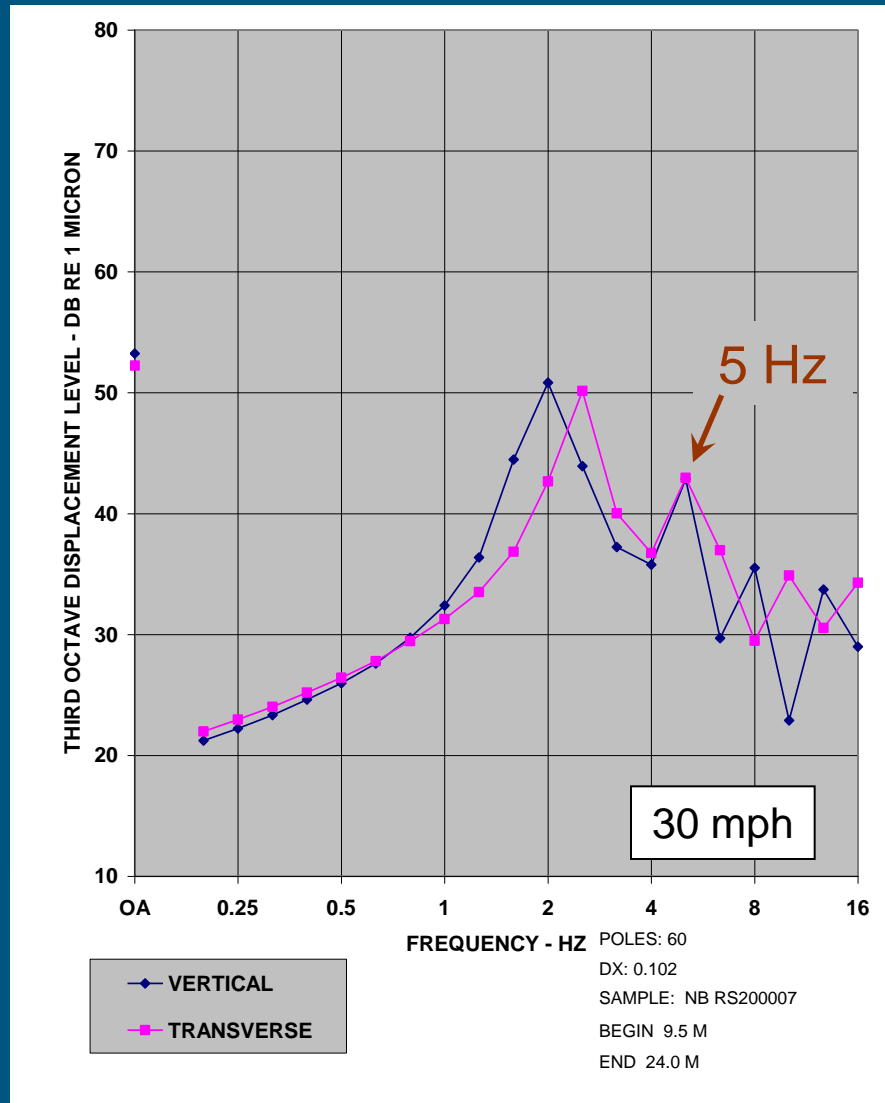
Rail Straightness Measurement



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