SOUNDTRANSIT

RAIL TRANSIT SEMINAR

Shankar Rajaram

Executive Director,
Sound Transit

August 26-28, 2025

WRI2025RT SEATTLE, WA

Overview of Sound Transit's Wheel Rail Interface Management Strategy

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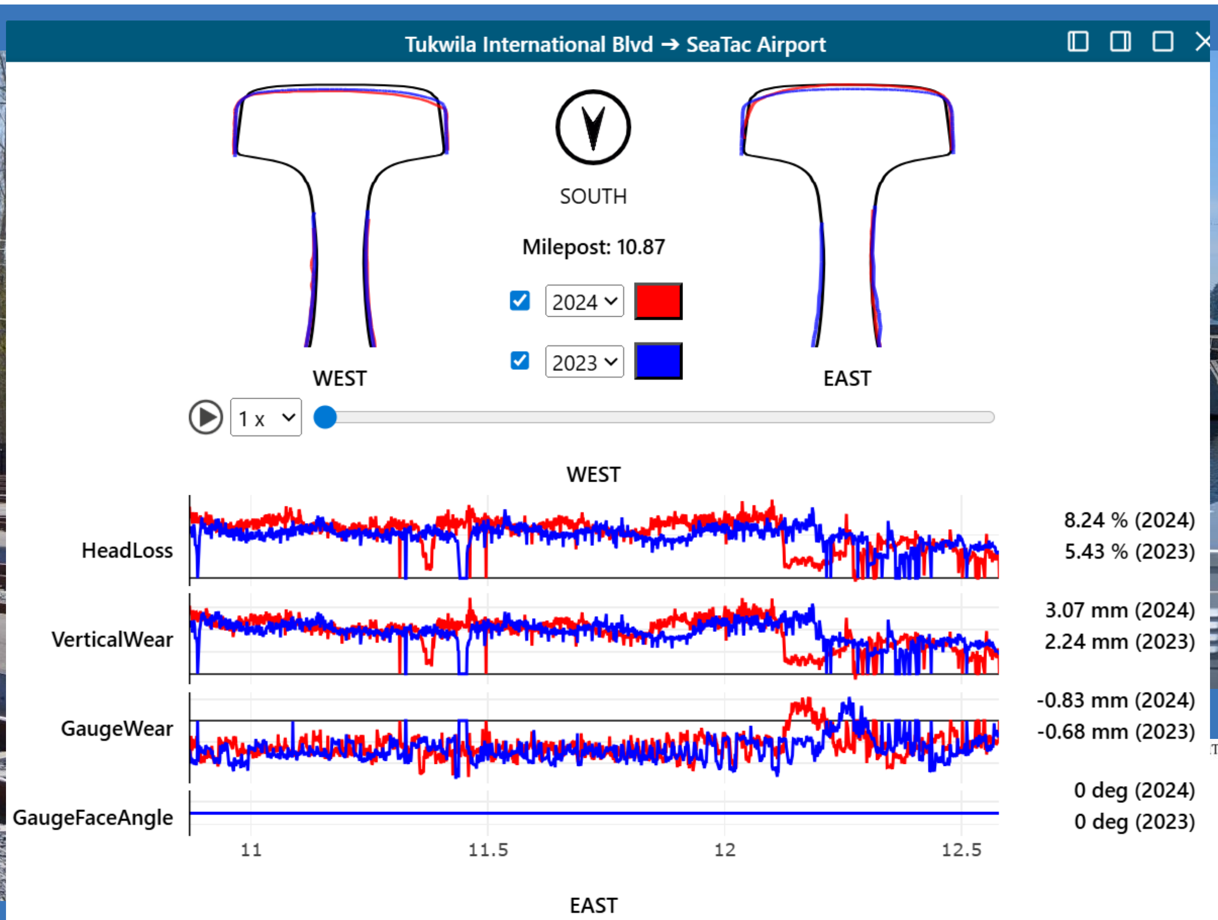

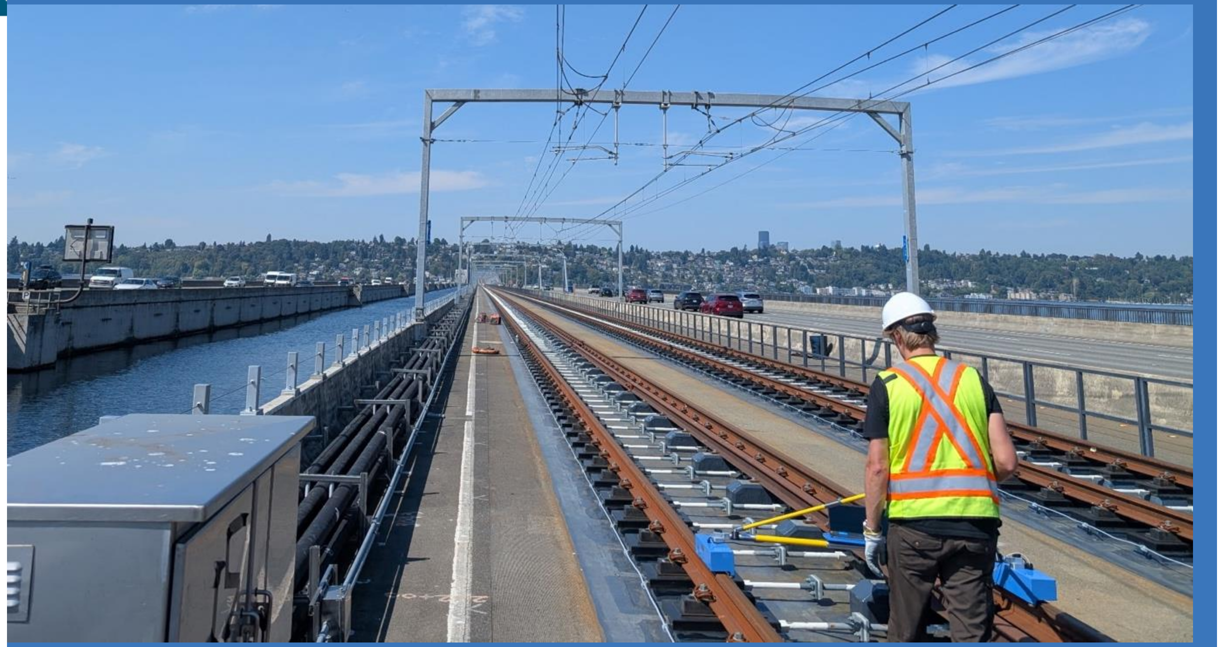

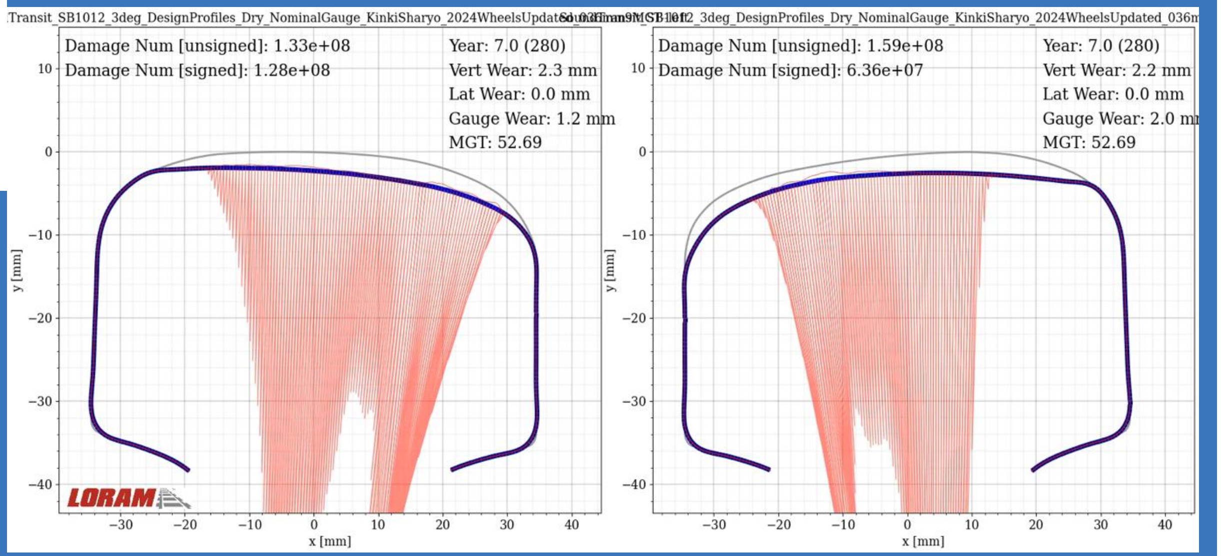

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(Acting) Executive Director-Core Infrastructure & Asset Management

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Acknowledgements

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- **Stuart Grassie** – Stuart Grassie
- **Briony Croft, Mark Reimer** – Sahaya
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- **Jim Nelson, Derek Watry, Luke Watry, Katie Krainc** – Wilson Ihrig Associates
- **Shannon McKenna** – Cross Spectrum Acoustics
- **Chris Layman** – Chris Layman Associates
- **Hugh Saurenman** – formerly ATS Consulting
- **Partick Romero, Steven Wolf** – WSP
- **Hatch, Mott McDonald, National Research Council of Canada, IEM**

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Link Light Rail Alignment & WRI

- Link light rail is ~40 miles long today and will be ~55 miles long in less than a year.
- 115RE rail, relatively hard – 320HB or more is standard, sections of 370+ HB premium high strength rail.
- Direct fix slab track on elevated guideway and in tunnels. Embedded or ballasted surface track at grade.
- 70% Low-floor articulated LRVs with resilient wheels and max operating speed is 55 mph.
- Each LRV is 95-ft long with two power trucks with solid axles and one trailer truck with independent rotating wheels.

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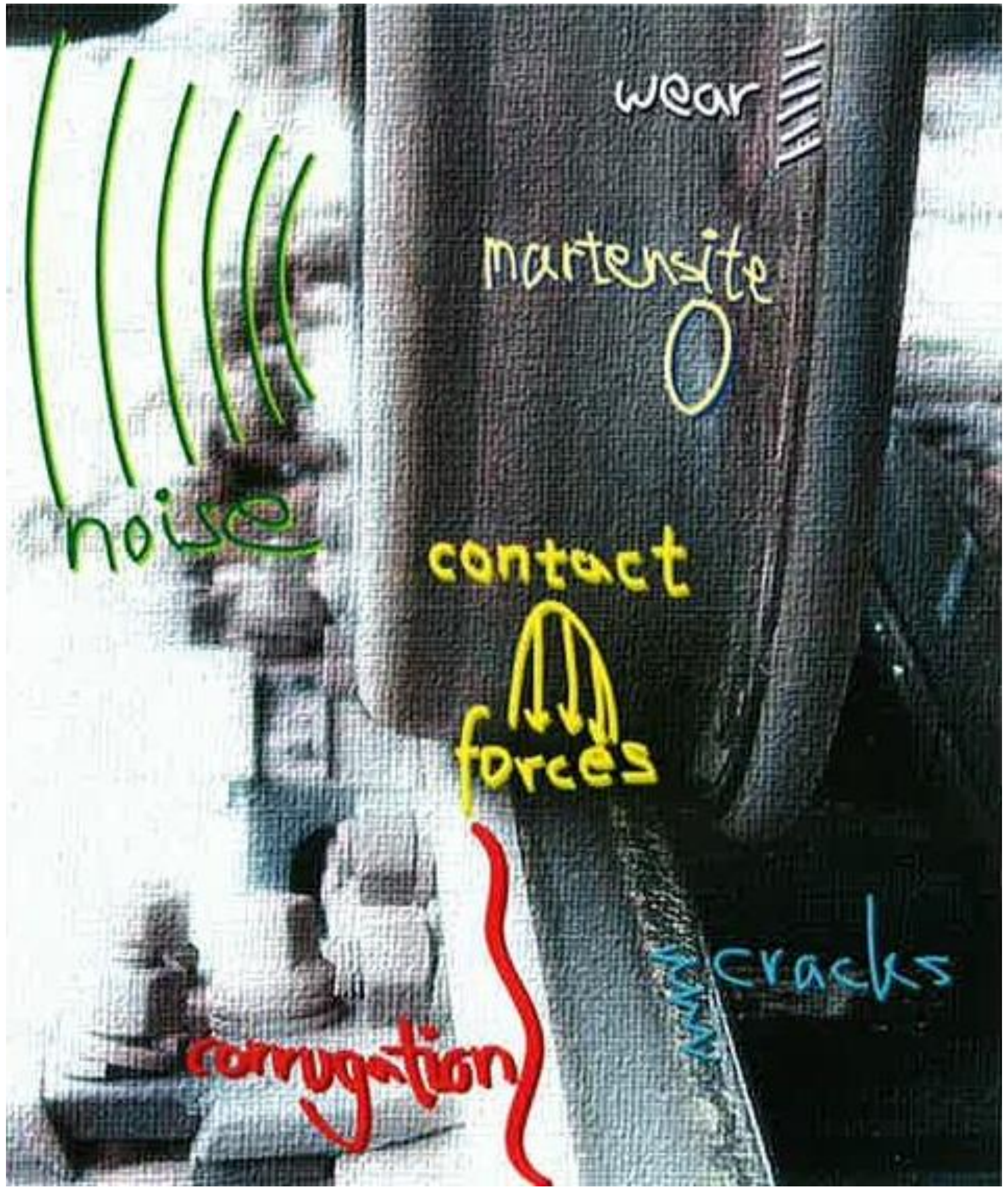
WRI Focus

- Rail Profile
- Rail Surface Condition
- Wheel Profile
- Wheel Surface Condition
- Spring and Damping systems
- Performance Properties: Noise, Vibration, Ride Quality, Rail and Wheel Wear, Defect Formation, and Maintenance Cost



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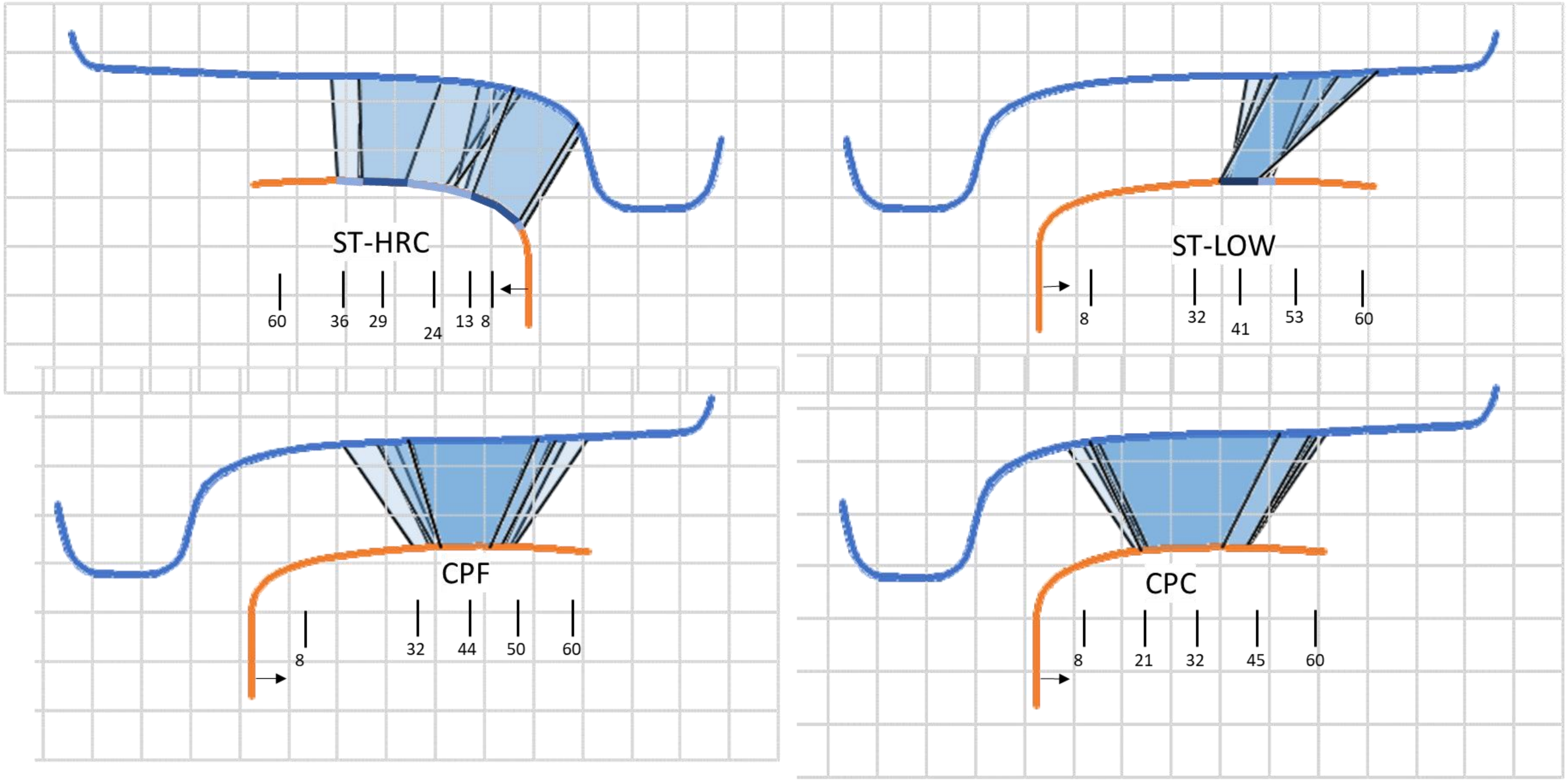
Rail Profiles



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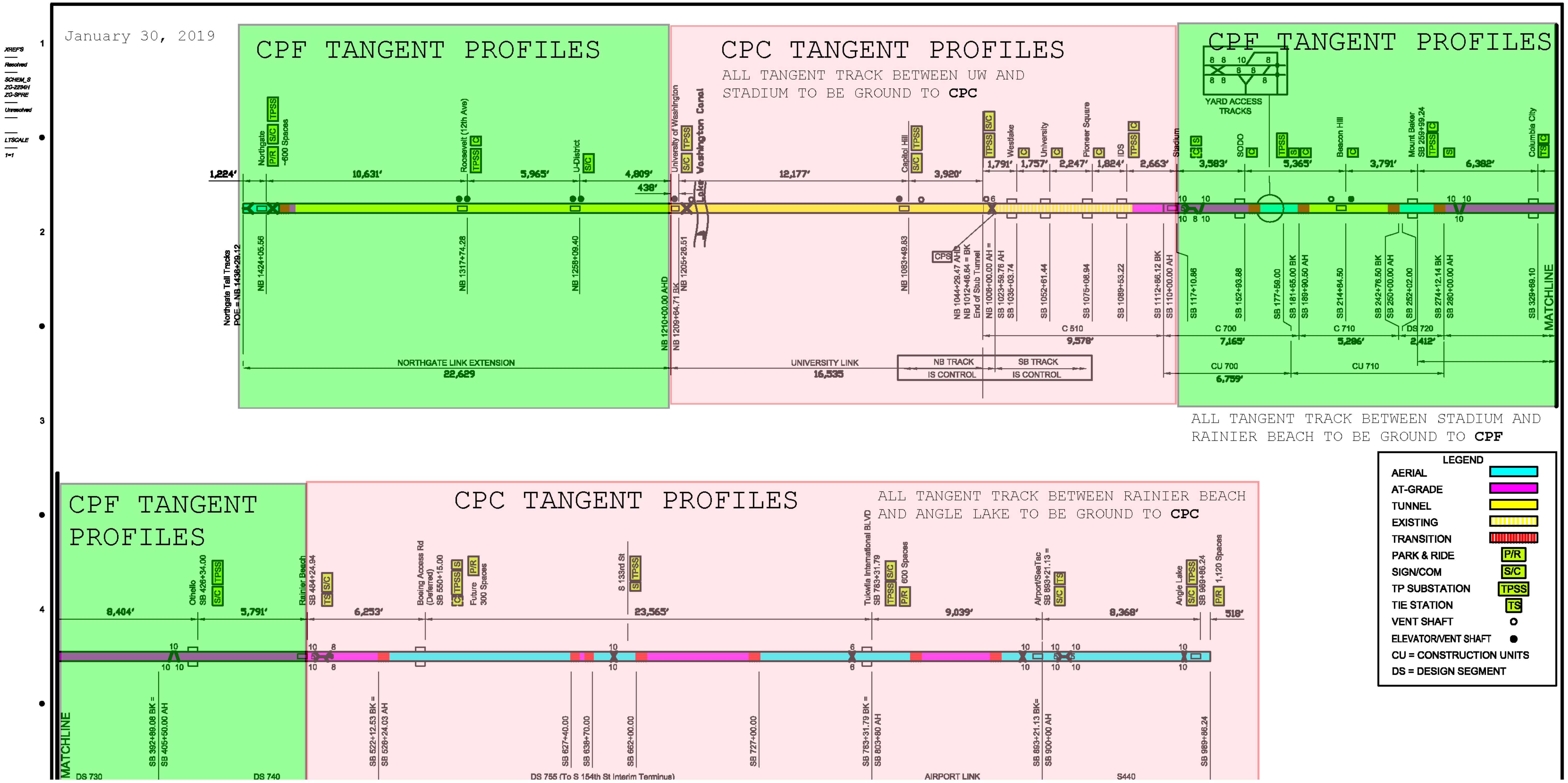
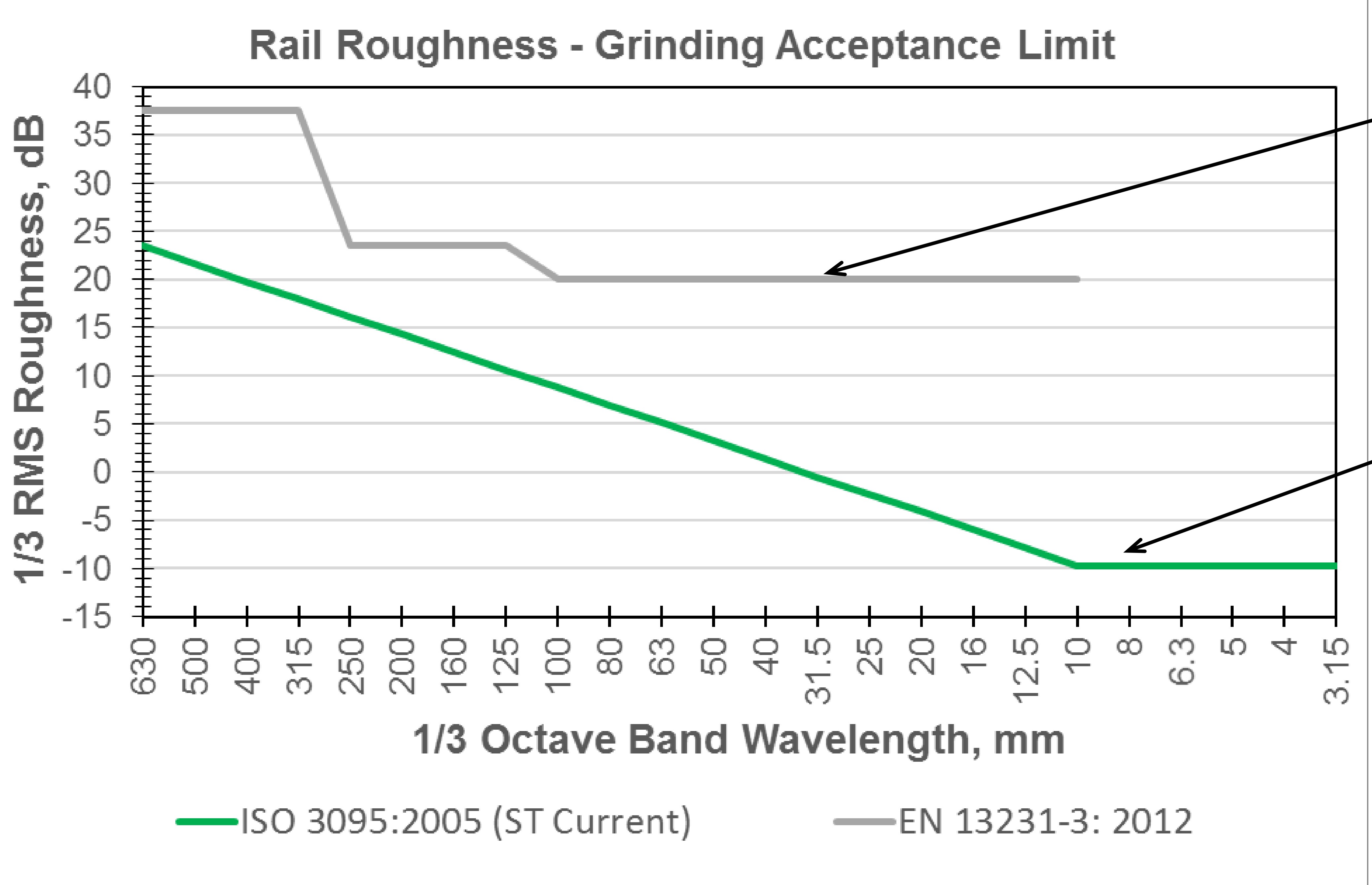
Rail Profile Distribution on Link Light Rail



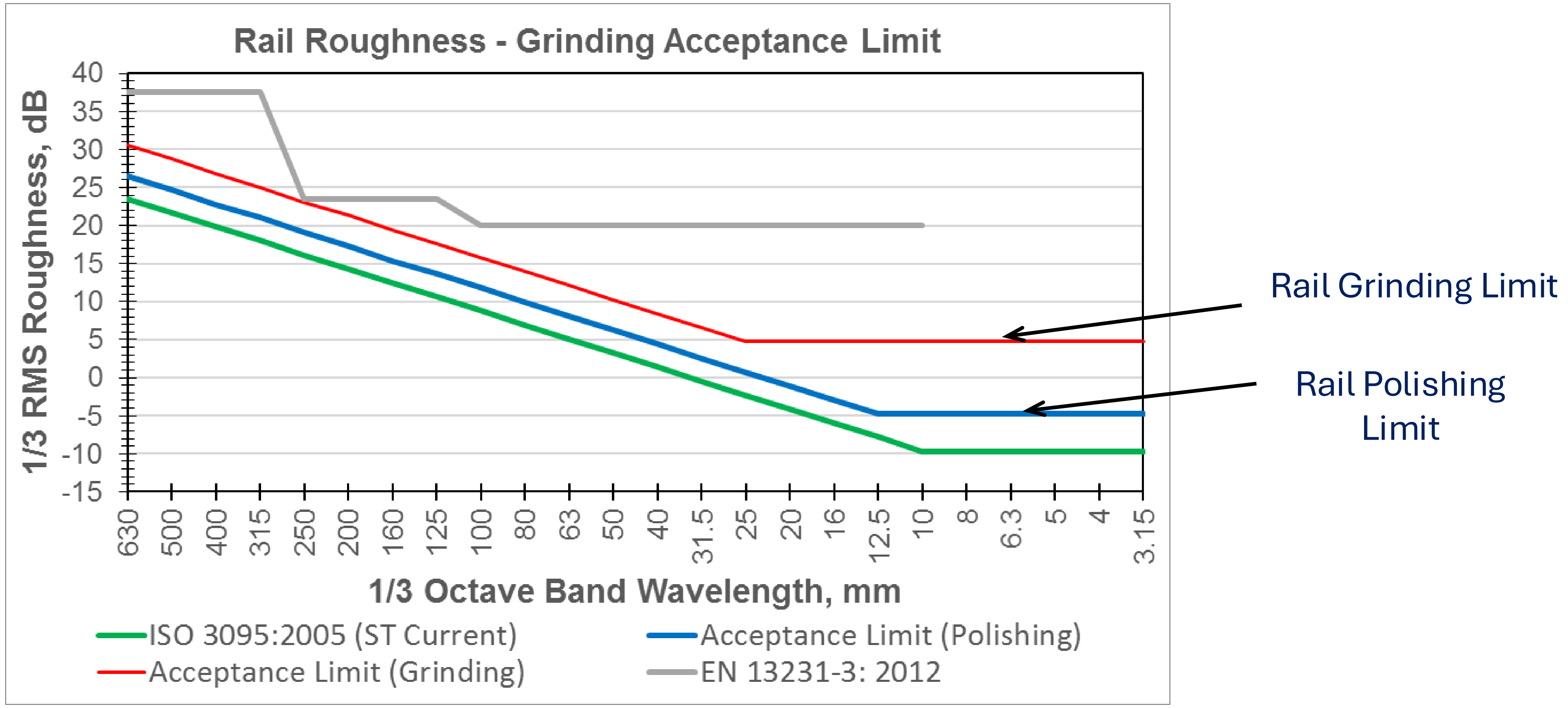
US Transit Rail Grinding Performance Criteria: Pre-2018



EN 13231-3:2012
Limit Proposed by Rail Grinding Companies

ISO 2095: 2005
ST's Current Rail Grinding Limit

Sound Transit's 2018 Rail Grinding Critieria



- First for North America
- Higher "grinding" limit for reprofiling / higher metal removal grinding
- "Polishing" as second step targeting smoother rails, residual grinding signature shifted from 32.5mm wavelength band to 50mm

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Rail Profiles

For a 3600 RPM grinder on DF tracks or Ballast & Tie Tracks, 2 steps used:

- **Grinding step** – use coarse stone and slow speed (**4 mph**)

  Shapes the rail profile.

- **Polishing step** – use softer stone and faster speed (**6mph**)

  Finishes the surface.

Grinder Speed, RPM, and Stones

Setup	Stone	Amperage	Grinder Speed	Comment
1	909M	20-22	4 mph	Medium grit for step 1 grinding
2	909F	24	6 mph	Fine grit, high speed polish attempt
3	909F	24	3 mph	Fine grit, low speed polish attempt
4	909XF	22	4 mph	Extra fine grit polish
5	SGAF	22	4 mph	Extra fine, different stone supplier
6	909XF	24	6 mph	Extra fine grit, final preferred setup

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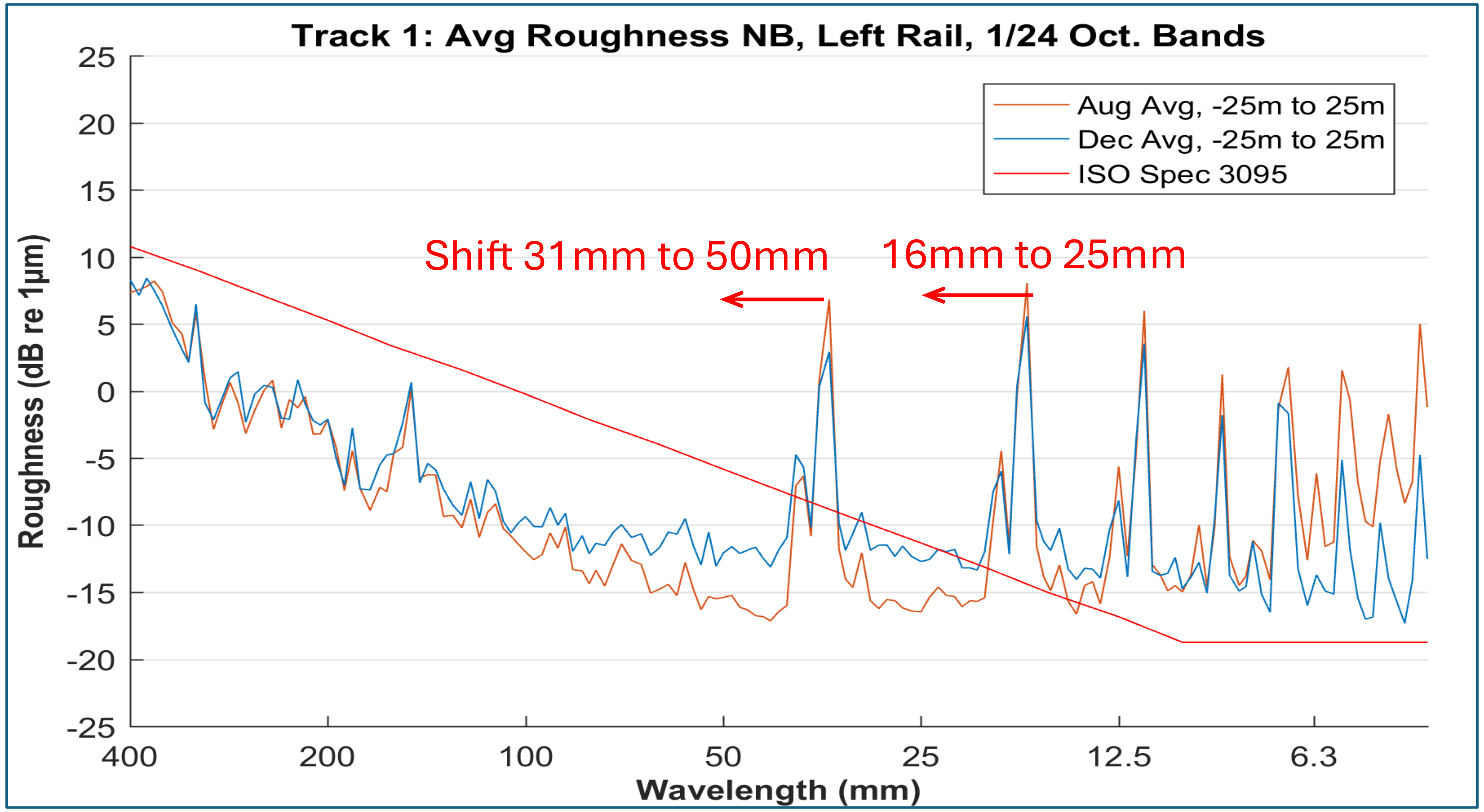
Sound Transit's 2018 Rail Grinding Standard

- Top left: In 2016 approximately 5 miles (8 km) of track entered revenue service after rail target profile installation left coarse residual grind marks. This image is the grind signature still present 2 years after coarse grind.
- Top middle: after grinding with medium grit stones.
- Top right: after acoustic polishing step.

Fundamental Strategy to Rail Grinding



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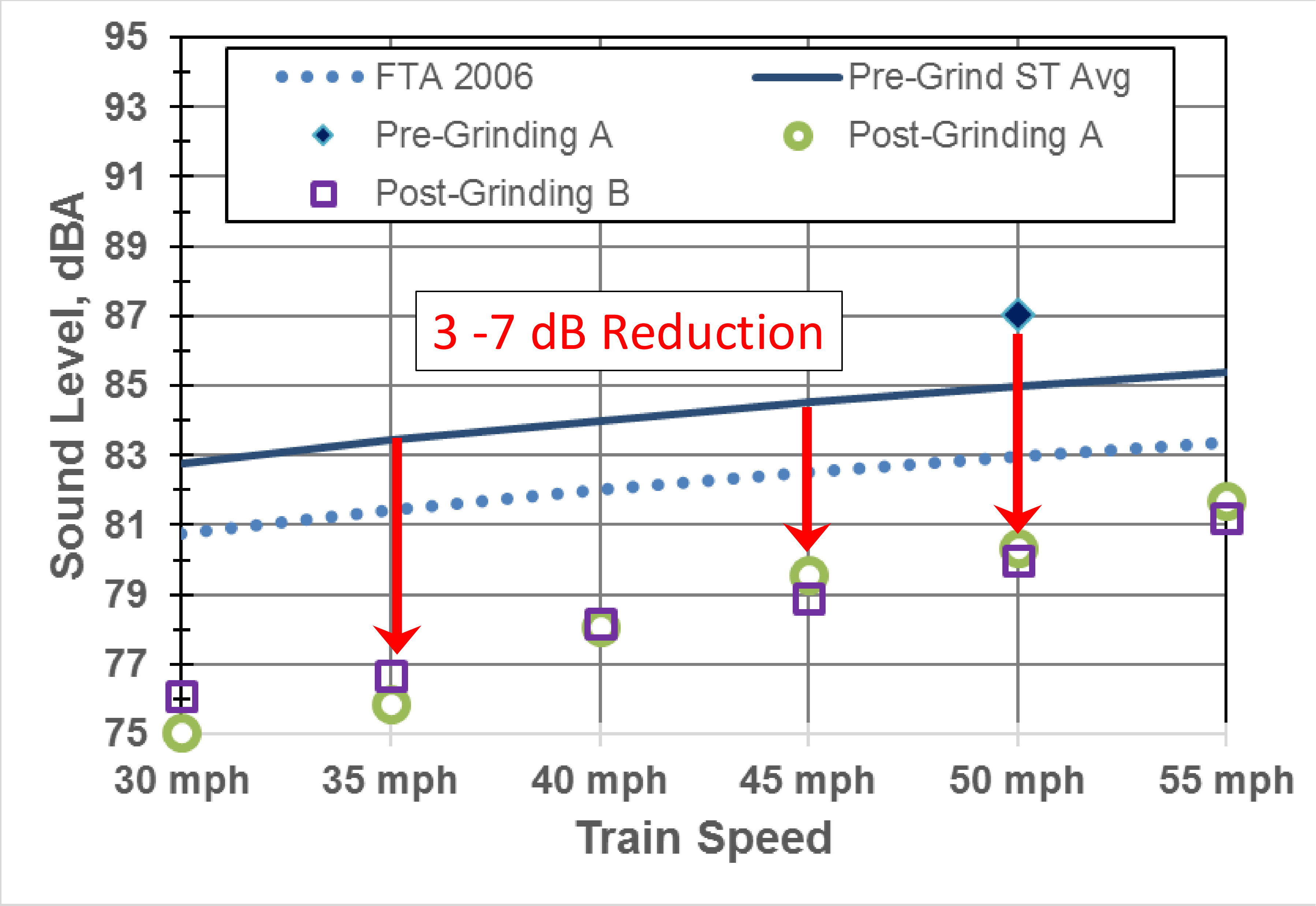
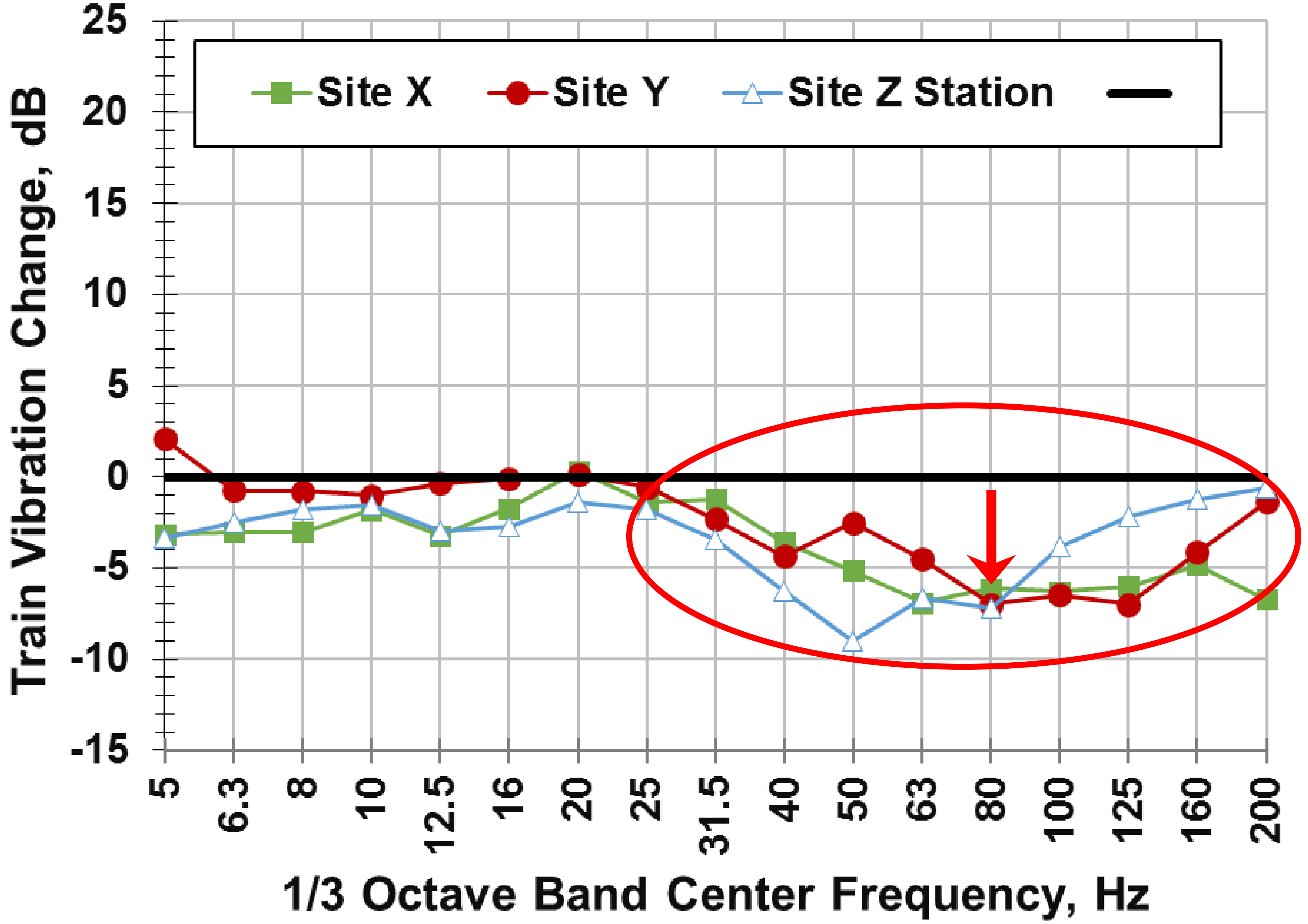
Wayside Noise and Vibration Benefits of 2018 Rail Grinding Specification





Peak train vibration and groundborne noise frequency

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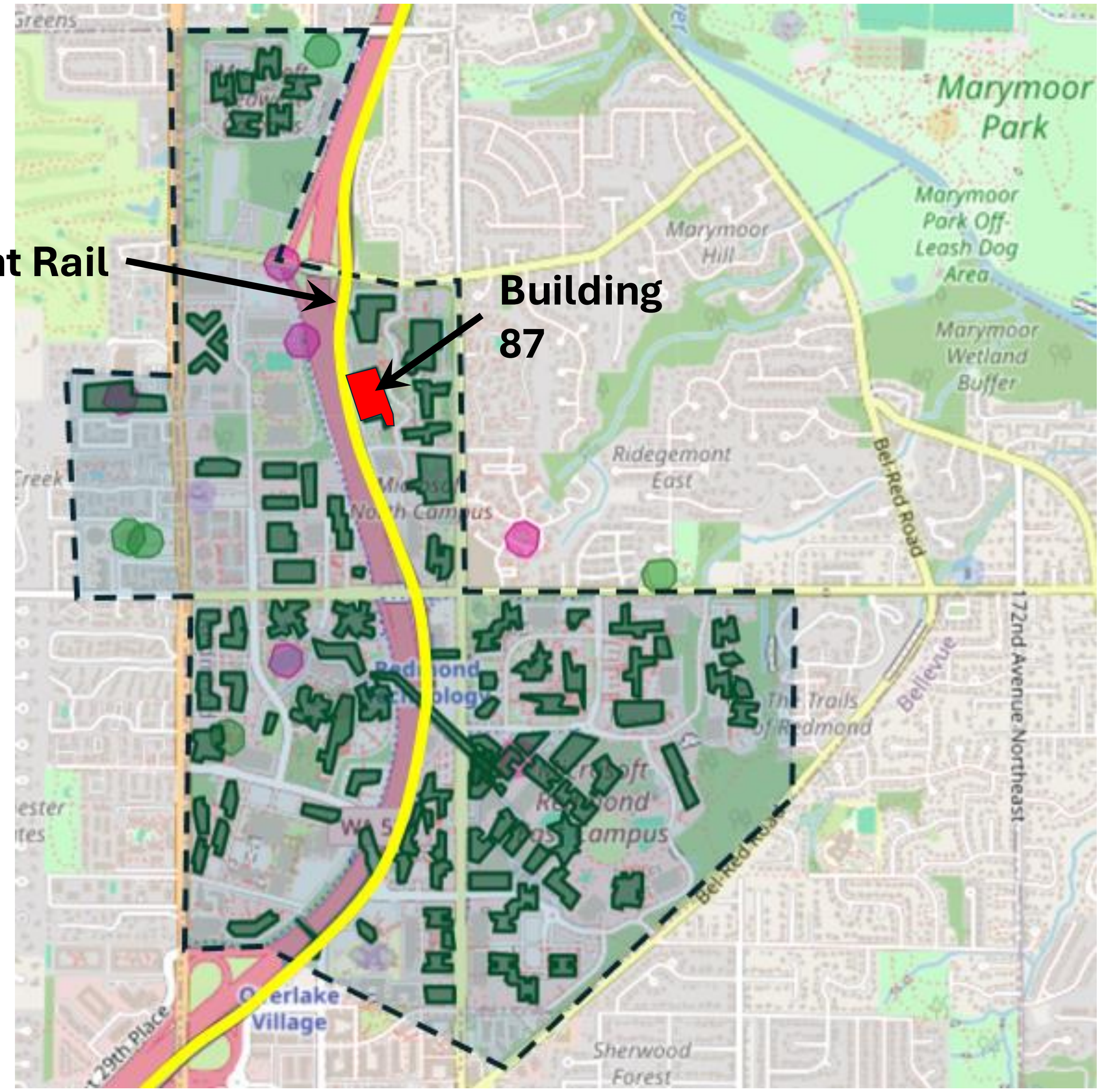
Noise and Vibration Benefits of 2018 Rail Grinding Specification

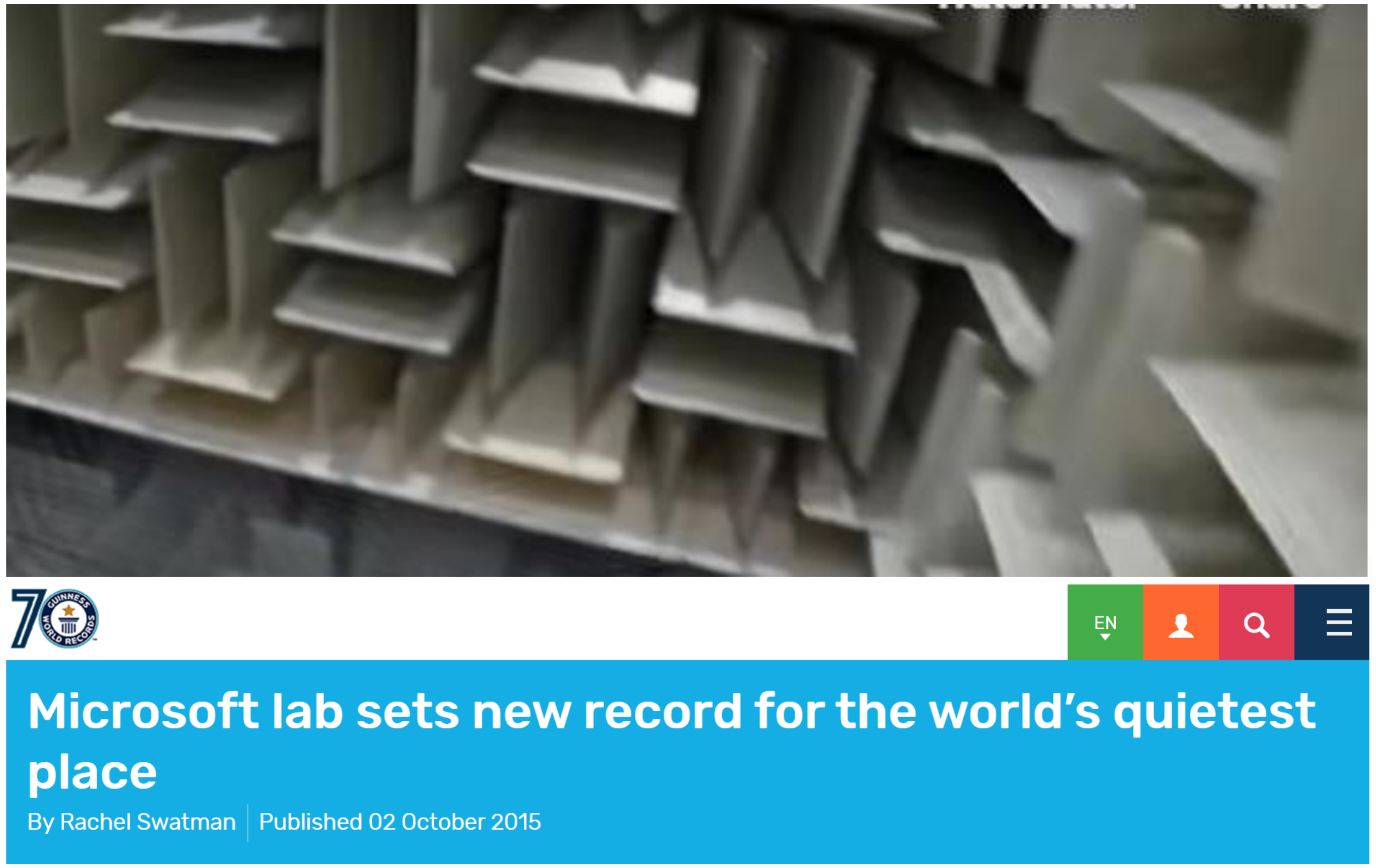
- Noise Reduction: 3-7 dBA
- Vibration Reduction: 1-3 VdB

Lynnwood Link	Floating Slab (Linear Foot)	Ballast Mat (Linear Foot)	Noise Walls (Sq. ft)
Pre-Grind	2,750	7,850	154,836
Post-Grind	0	4,000	128,172
Total Reduction	**2,750**	**3850**	**26,664**

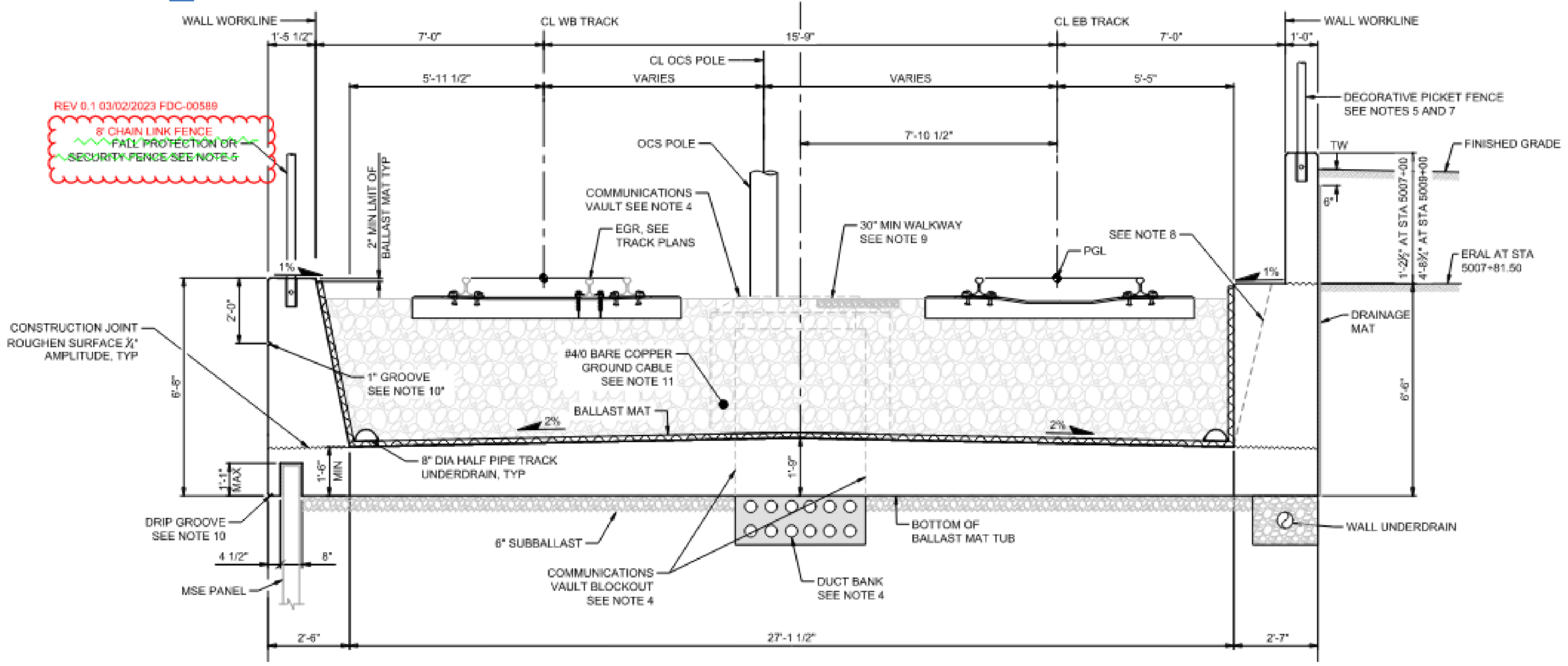
Federal Way Link	HCDF (Linear Foot)	Ballast Mat (Linear Foot)	Noise Walls (Sq. ft)
Pre-Grind	800	11,680	202,882
Post-Grind	0	3,600	110,054
Total Reduction	**800**	**8,080**	**92,828**

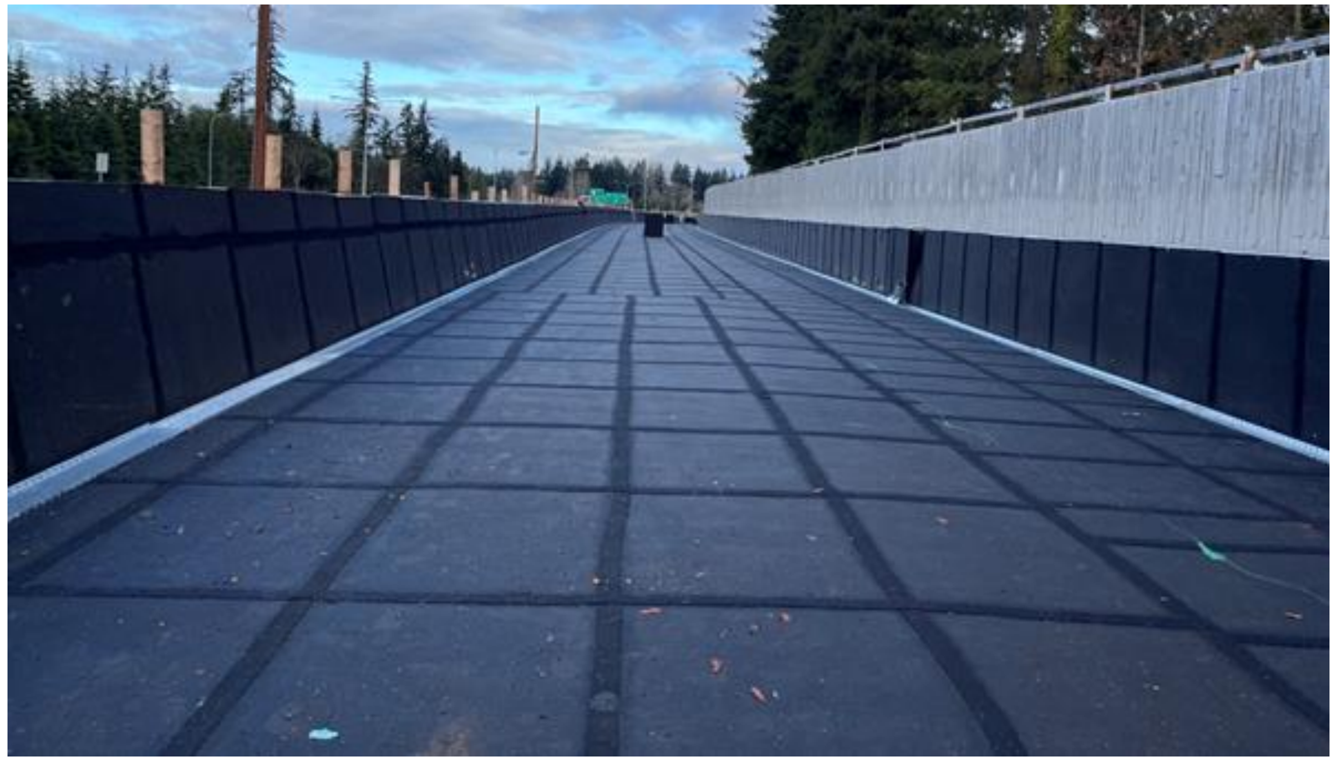
Downtown Redmond Link Extension – Ballast Mat Track





Downtown Redmond Link Extension – Ballast Mat Track





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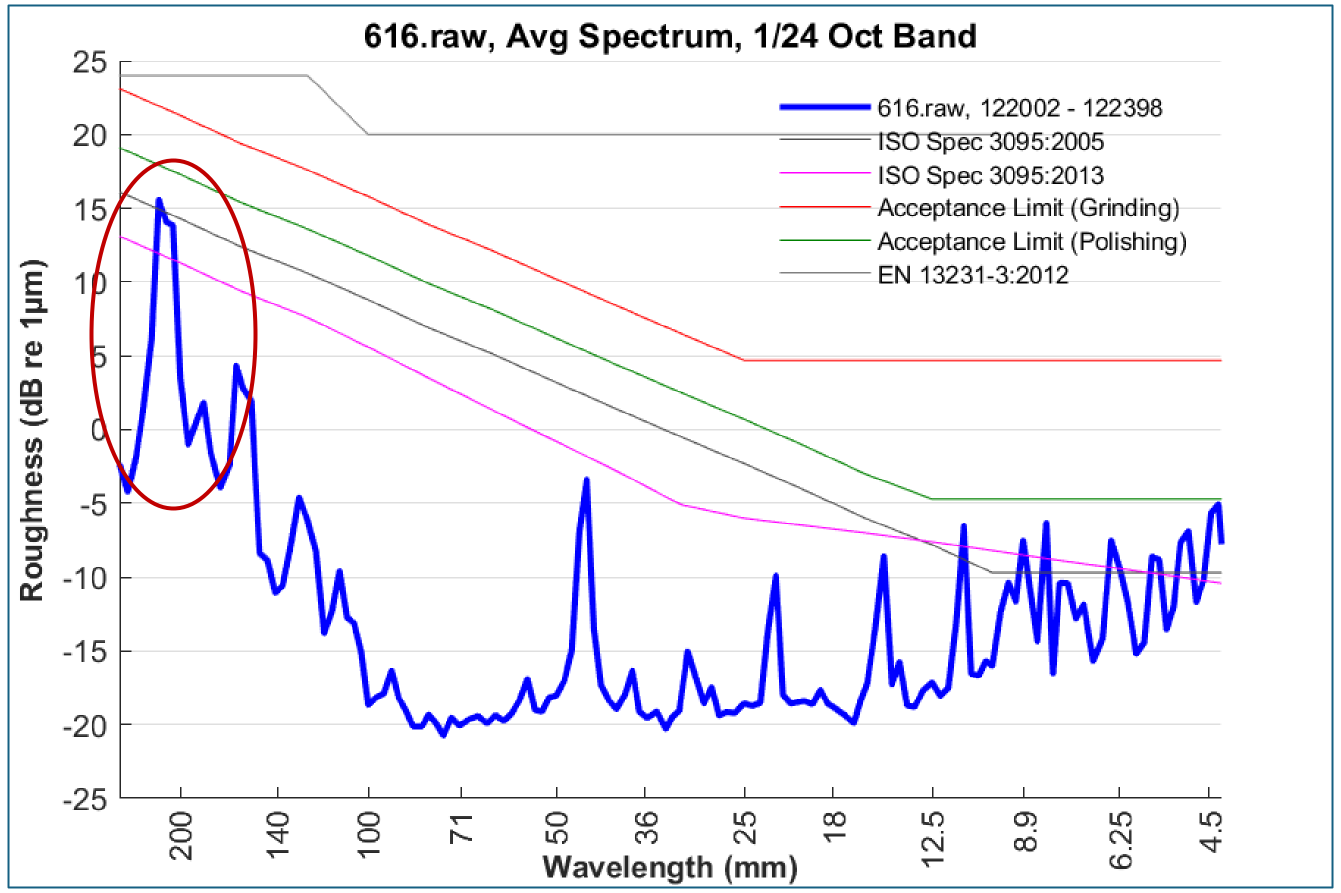
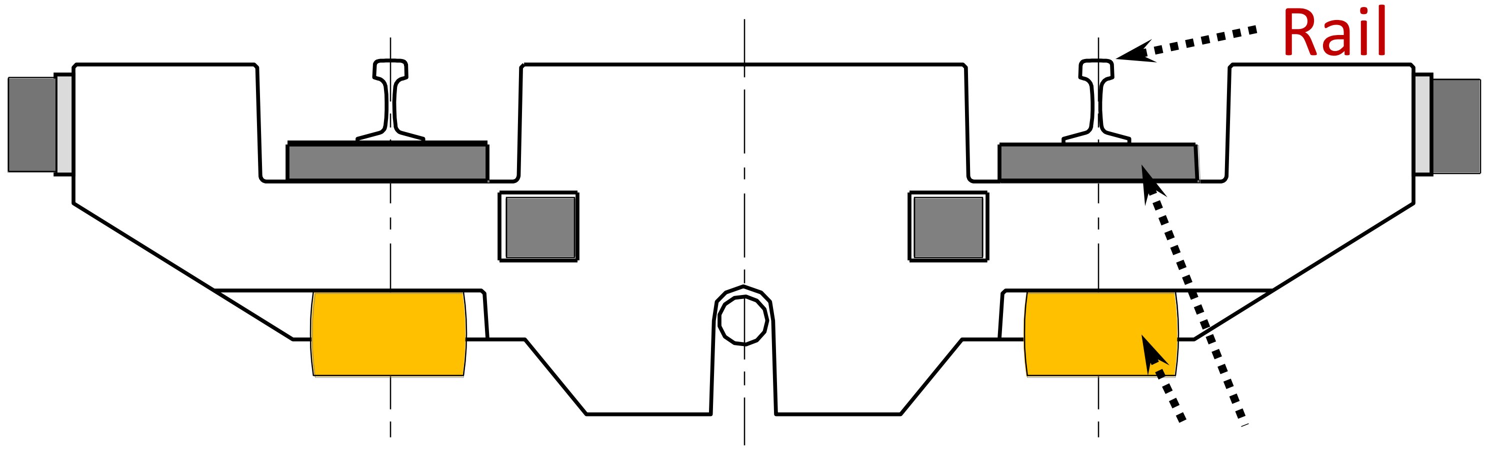
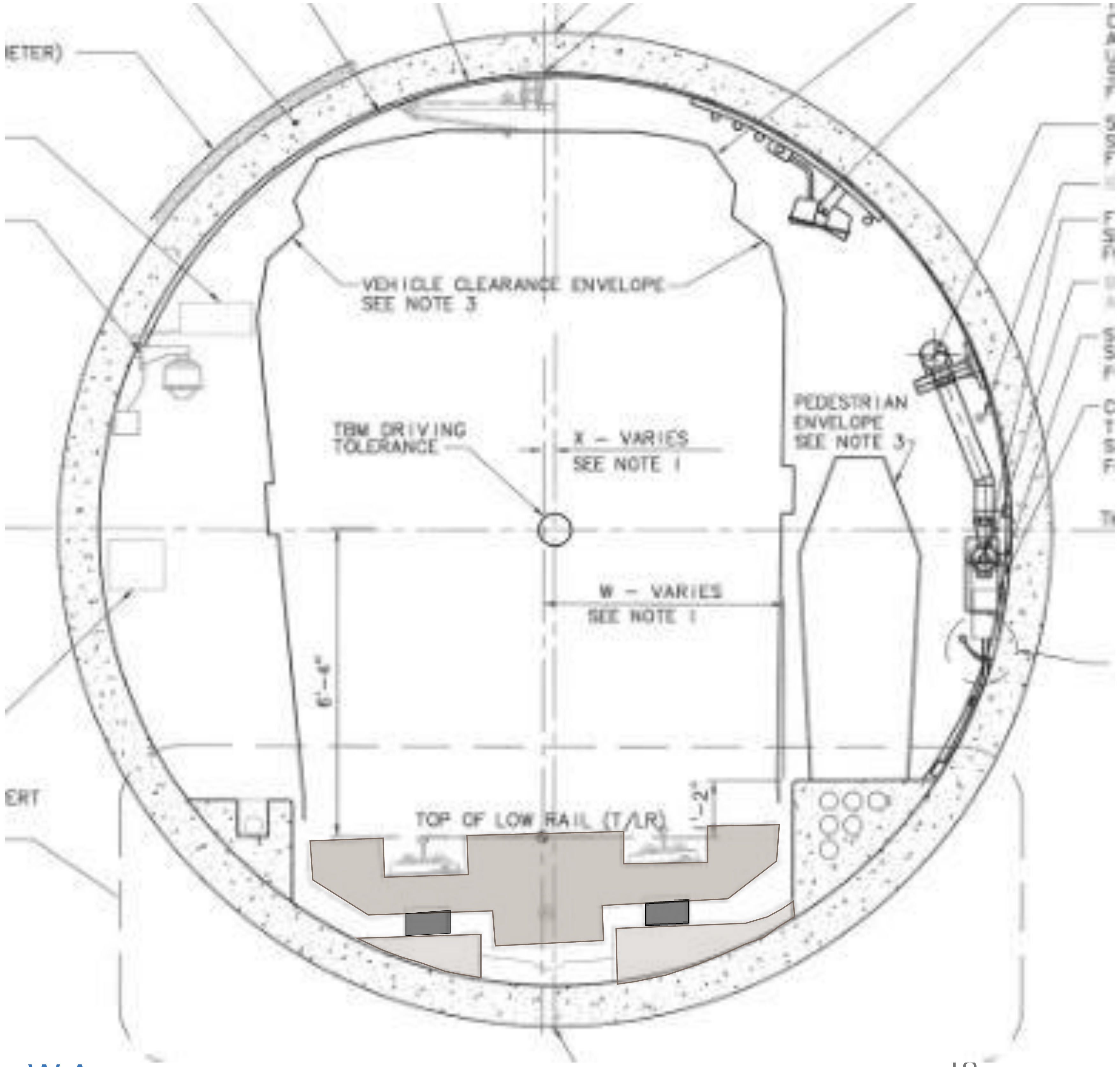
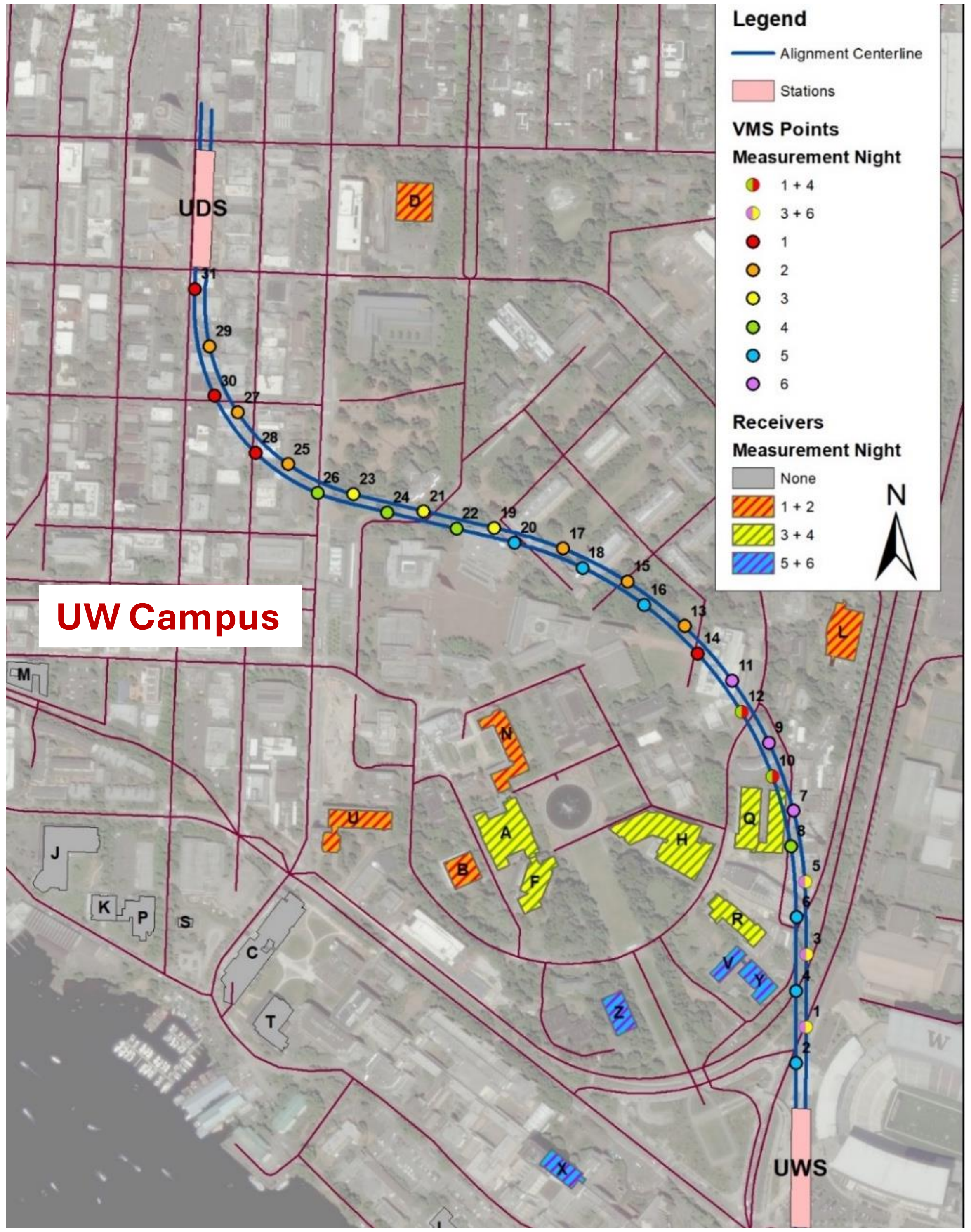
Rail Grinding on 5 Hz Floating Slabs at UW



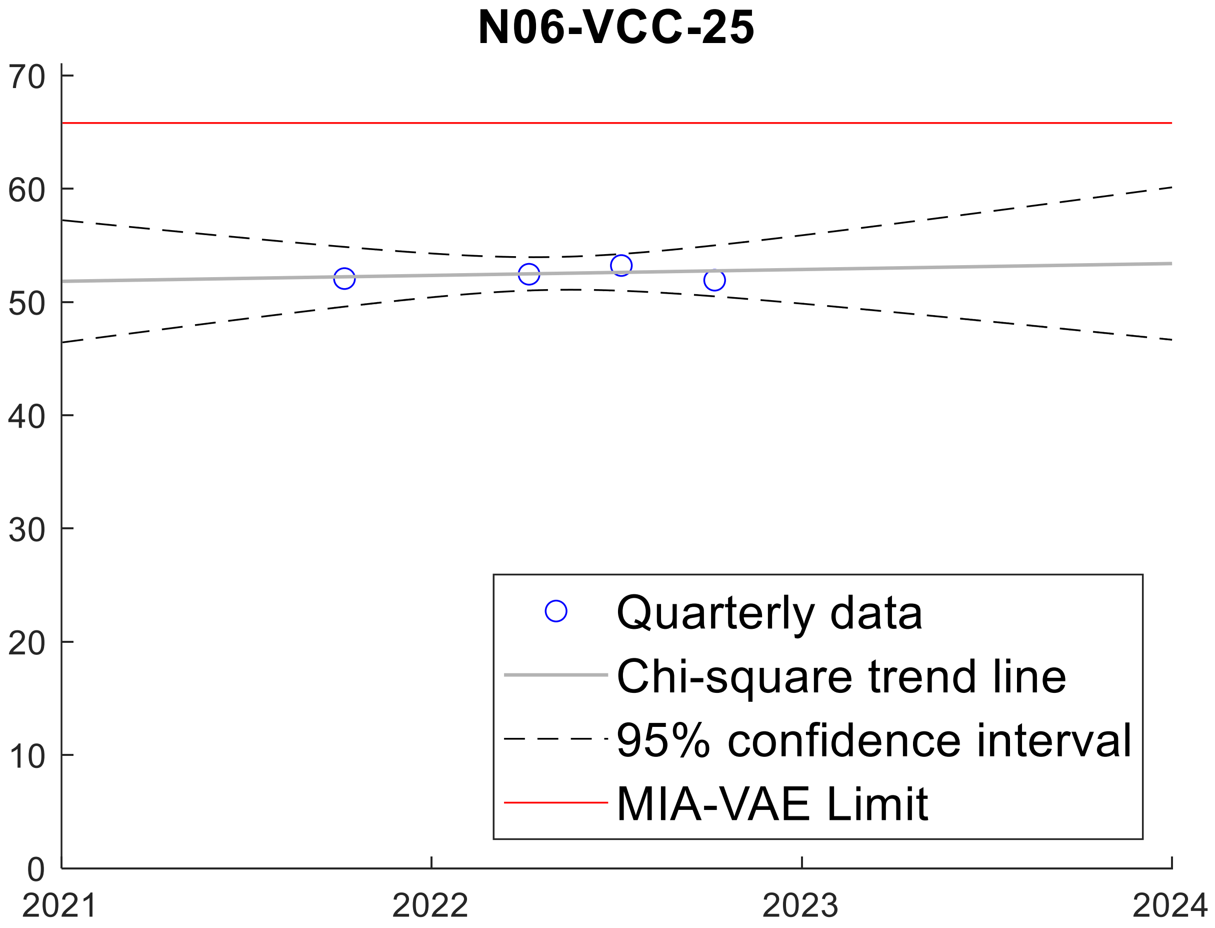




Vibration Monitoring at UW



- 40 vibration monitors
- One monitor every 91.5 m (300 feet)
- Smart Alarm System
- Early Warning System – 4 wheel flat detectors



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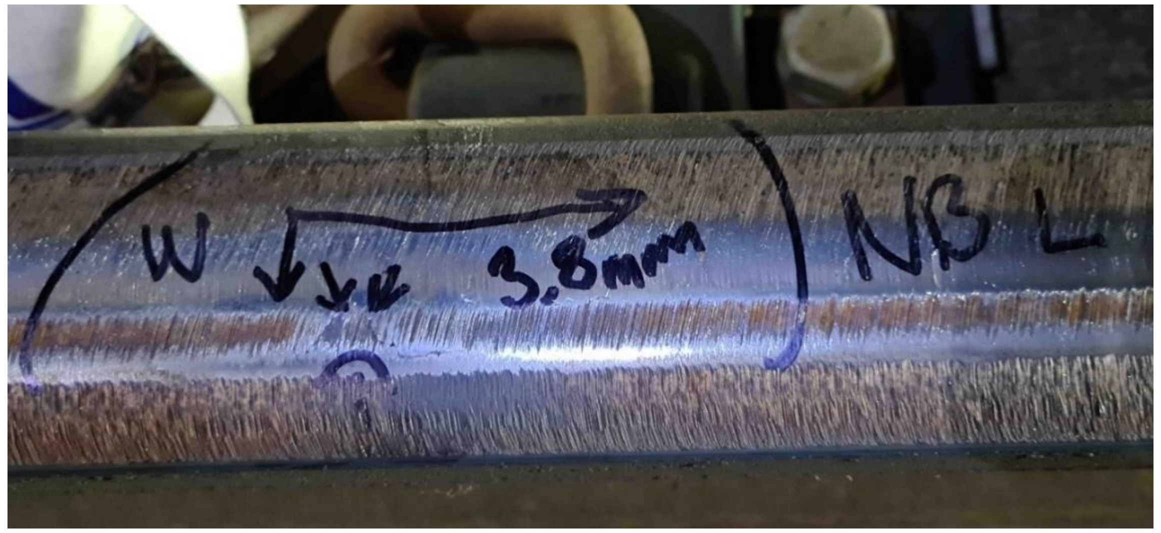
Rail Studs



Small stud

Medium stud (individual or periodic)

Severe stud (spalling of rail surface)

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What are factors driving studs?

- **The factors leading to the formation of studs is not fully understood in the industry.**
- Original grinding in 2009-2010 leading to with thermal impacts on the rail?
- Wheel slippage due to gradient, lubrication etc.?
- Higher rail hardness?
- Does return current plus aggravating conditions influence it.

Does Rail's Function as a Electric Conductor Have Anything to do with Stud Formation?

- Rail hardness: 260-280 BH is natural hardness of steel. Do heat treatment to make rails harder contribute to stud formation when rails have to manage return current?
- Are there traction power issues at substations that are within the rail areas with stud concentration?
- Does 1500 V DC voltage have anything to do with studs?
- Are there lubrication in areas with stud formation? Does lubrication act as dirt or grind dust catcher that in combination with return current create local electrothermal pockets initiating cracks?

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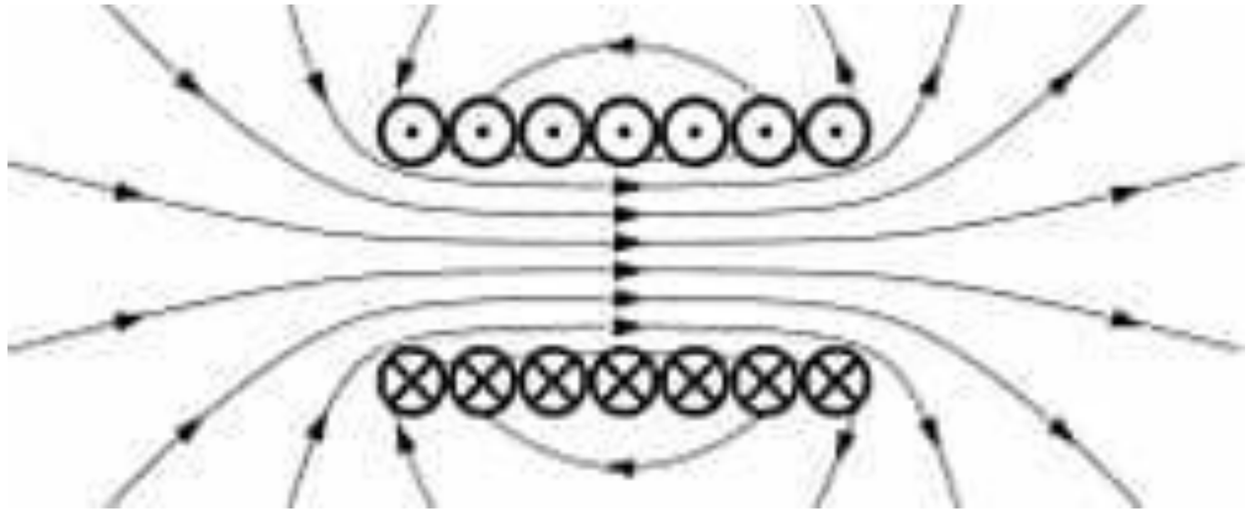
Rail Breaks

Year	No. of Broken Rails
2021	1
2022	0
2023	8
2024	5

- Sound Transit has experienced 14 rail breaks in the last 4 years.
- Majority of the breaks are at rail head weld repairs or thermite welds.
- Repair-welds are not easily seen and inspected in track.
- **Hypothesis**: Perhaps widely prevalent quality issues from COVID years (due to human stress factors) contribute to increased rail breaks in the last two years?

Strategy to Manage Rail Breaks

- Increase rail Ultrasonic Testing (UT) frequencies from once per calendar year.
- Adopt a new KPI is to reduce it to 3 breaks per year.
- Implement inspection with technology for early surface contact defect detections.



- Inventory all field welds and monitor conditions.
- Improve welding procedures.

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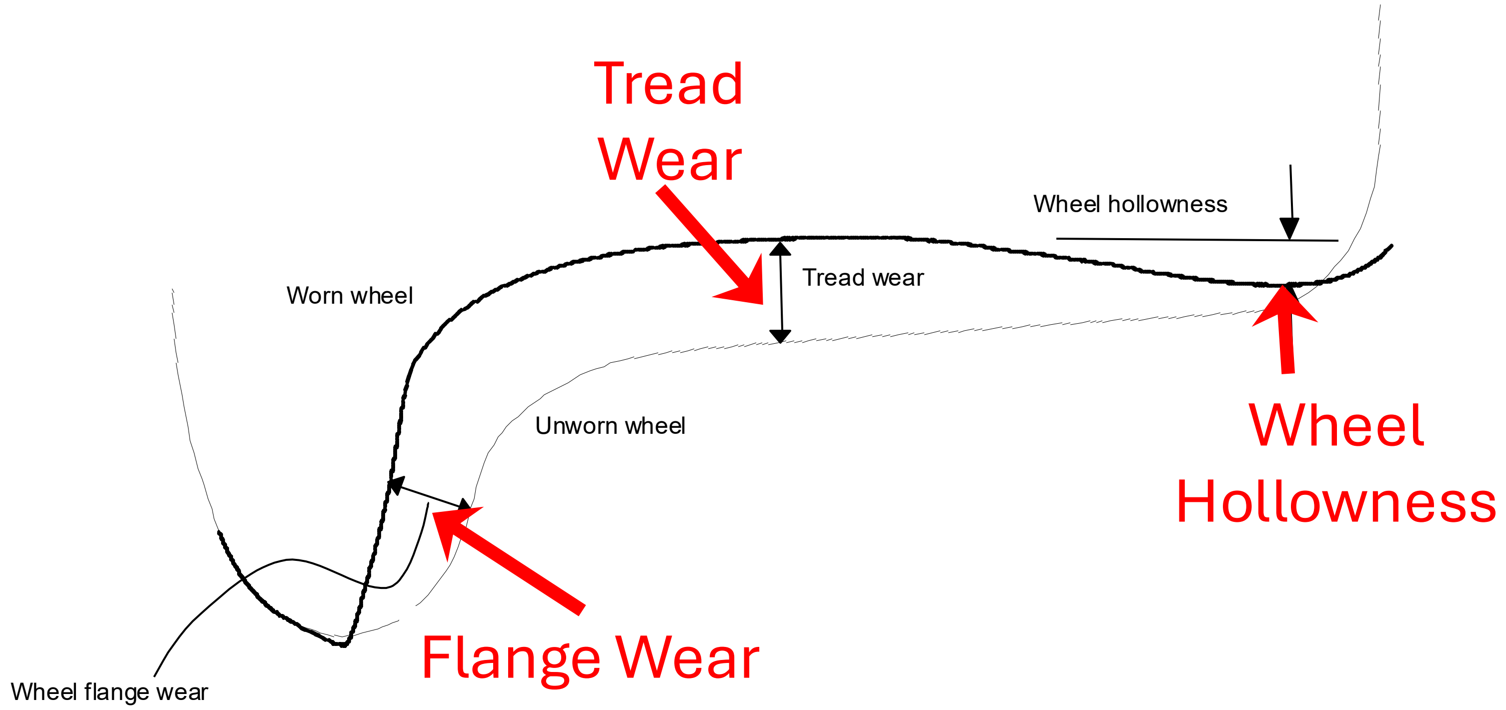
Wheel Rail Shape

System	Rail	Wheel taper (1 in)
Portland	115RE	30
Portland	Ri59	30
Newark	115RE	20
Hudson-Bergen	115RE	20
Santa Clara	115RE	32
Santa Clara	Ri59	32
San Diego	115RE	40
Houston	115RE	40
Boston	115RE	Formerly 40 now 20
Boston	149GCR	Formerly 40 now 20
Sound Transit	115RE	20

Wheel Rail Wear



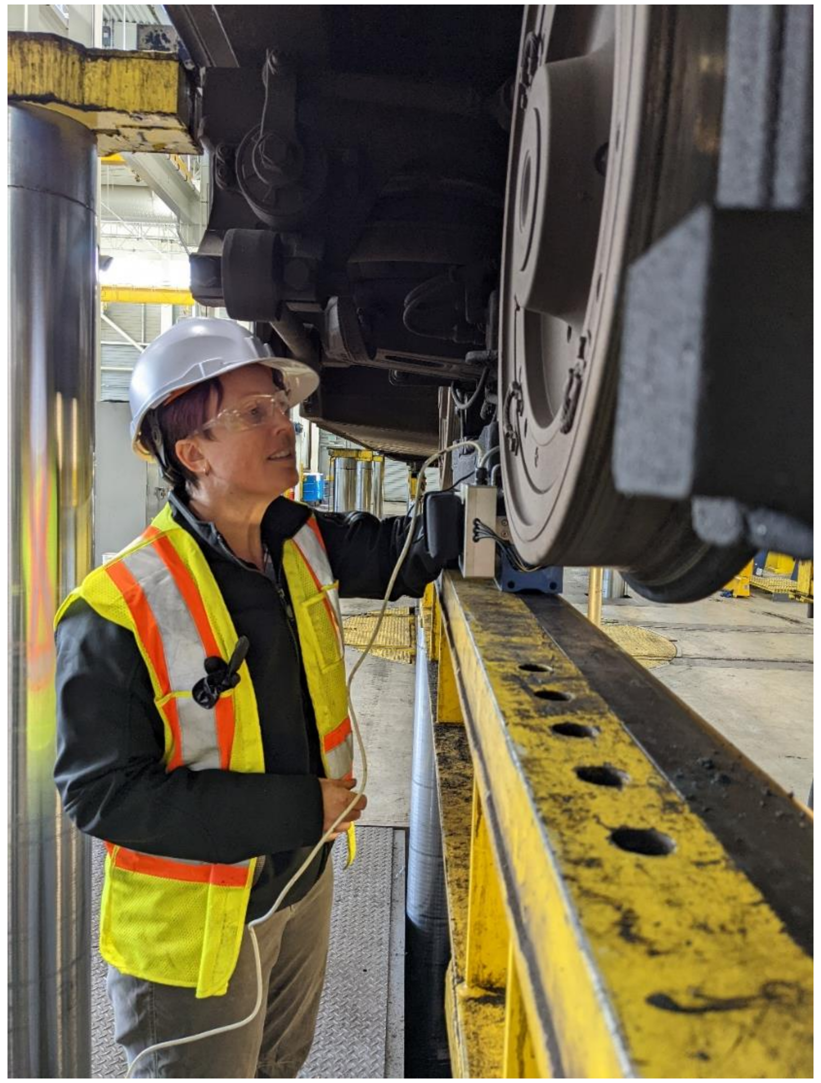
1-Pt Contact

2-Pt Contact

3-Pt Contact

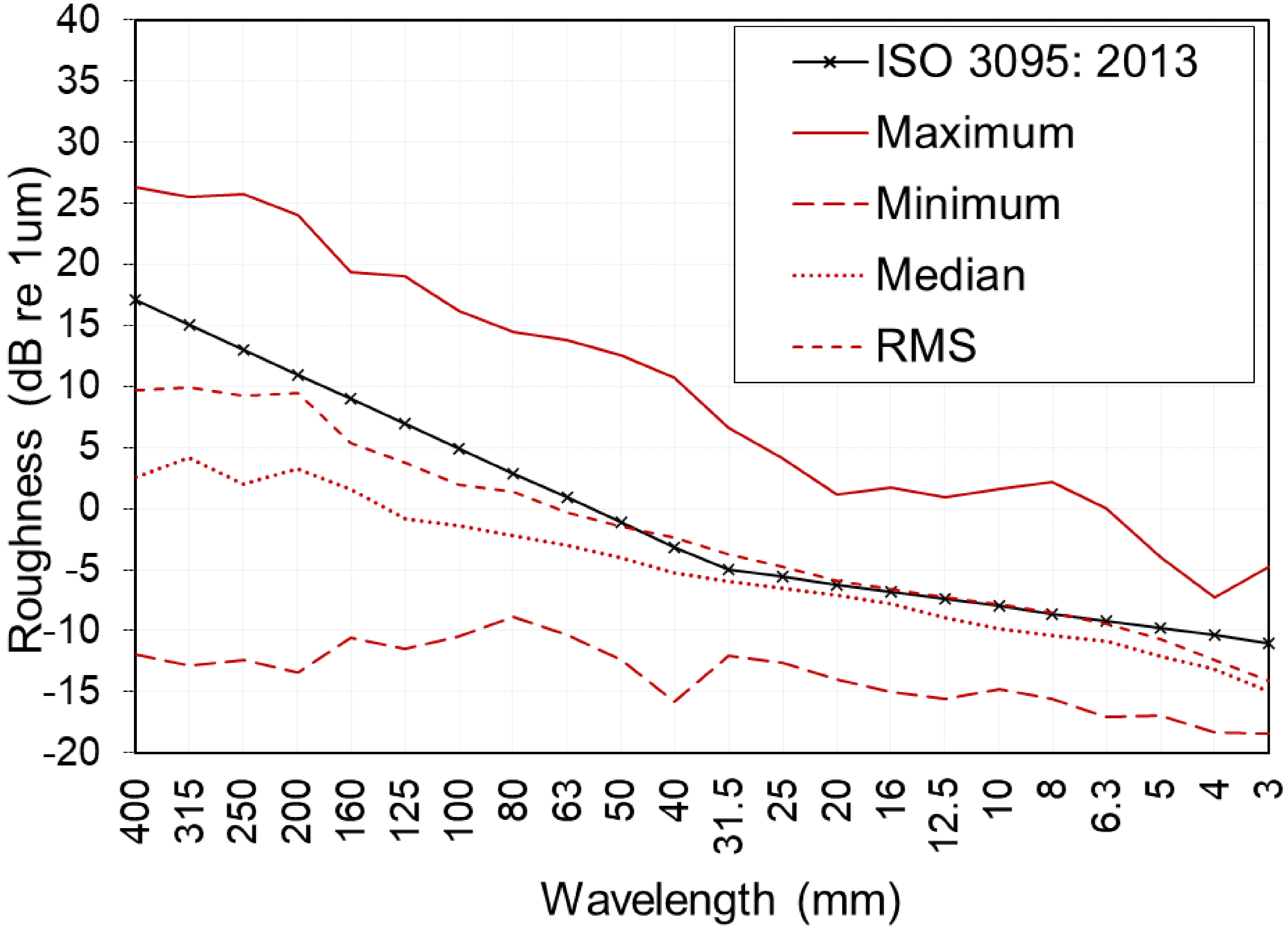
- Powered truck wheels showed higher hollowness
- Center truck wheels showed higher flange wear
- Powered axles hollow at ~4 times the rate of the Independent Rotating Wheels

Wheel Roughness

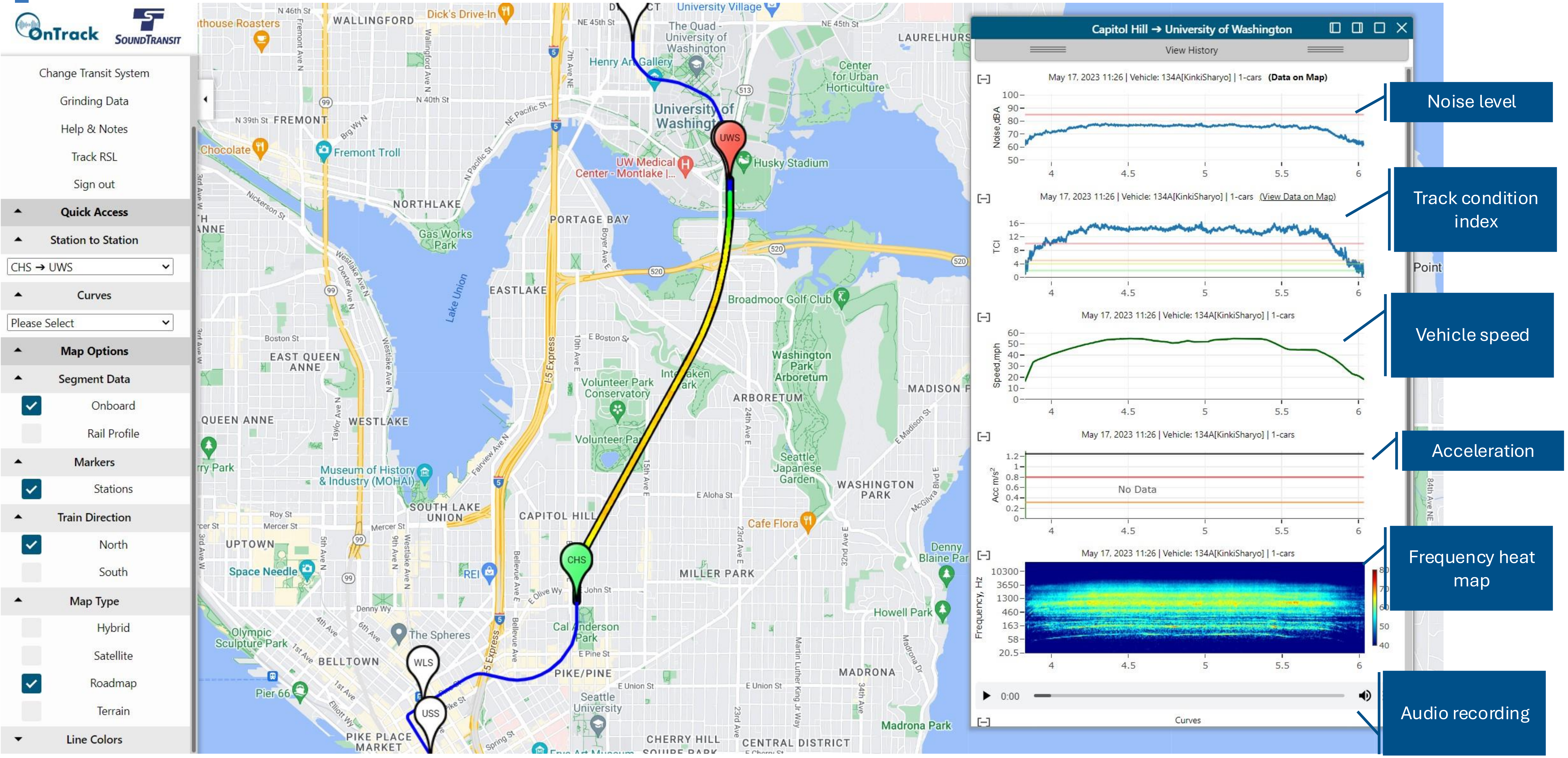


Wheel Roughness Summary

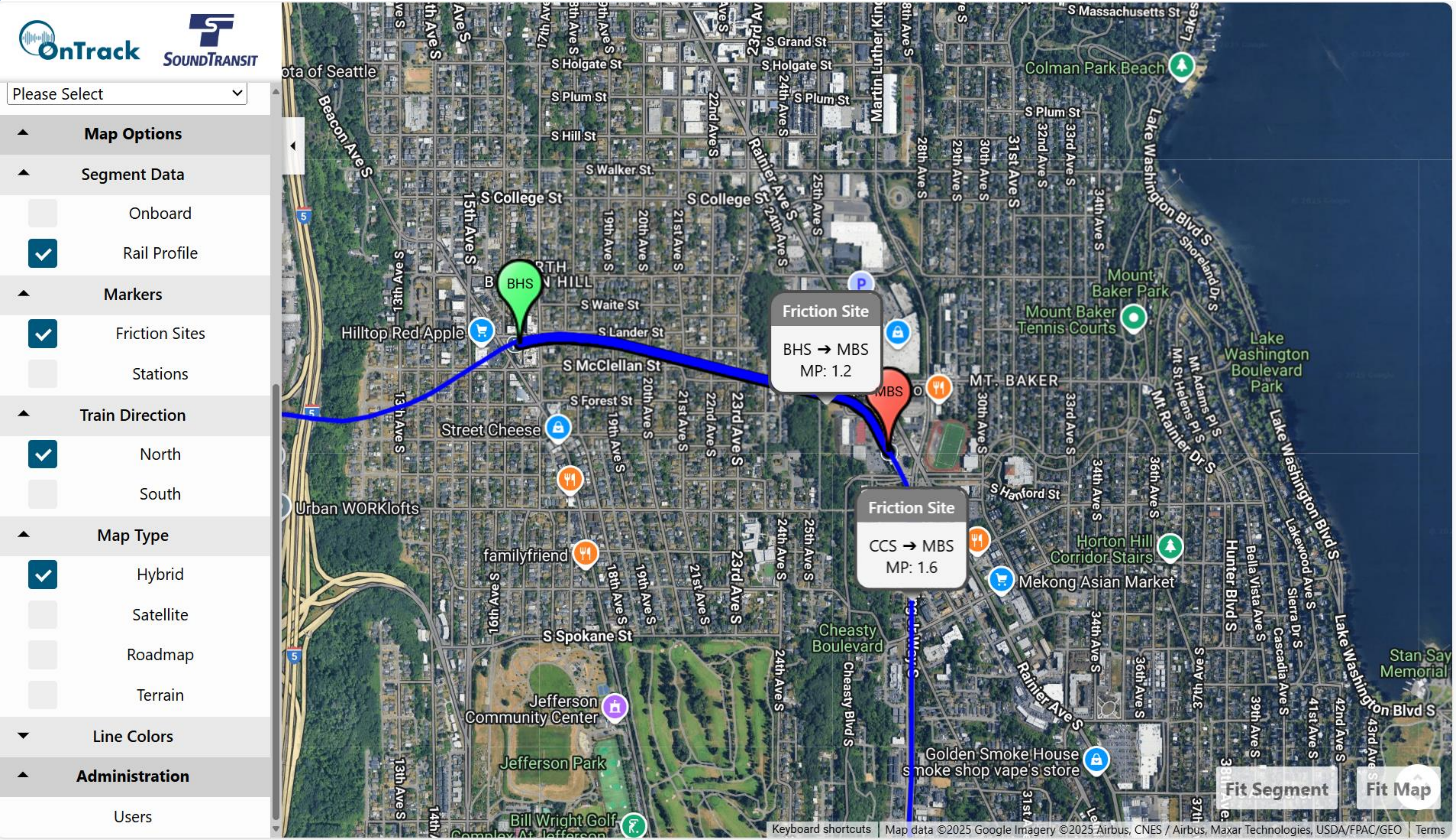
- Measurements of 204 wheels (124 after quality checks). Wheel mileage 0 to 198,000 miles.
- **RMS of all measured wheels similar to ISO 3095:2013**
- Wheel roughness in service independent of mileage – freshly machined wheels quickly wear in
- Some outliers, but unrelated to distance travelled
- General wheel acoustic roughness (excluding discrete defects e.g. flat spots) was also independent of the vehicle and truck/bogie type



OnTrack Tool



OnTrack Database: Friction Sites



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OnTrack Database: Grinding Data

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Grinding Data

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Date	Track	Begin...	End ...	Lengt...	Segm...	Com...	Shift ...	Work...	Grind...	Stone ...
2023-03-28	N1	0.18	0.24	317.00	Curve	TRUE	R-Regular	AGR	LRG-31	10 fine
2023-03-28	N2	0.32	0.43	581.00	Tan.	TRUE	R-Regular	AGR	LRG-31	10 fine
2023-03-28	N1	0.32	0.43	581.00	Tan.	TRUE	R-Regular	AGR	LRG-31	10 fine
2023-03-28	N1	1.01	1.13	634.00	Tan.	TRUE	R-Regular	AGR	LRG-31	10 fine
2023-03-28	N1	1.01	1.13	634.00	Tan.	TRUE	R-Regular	AGR	LRG-31	10 fine
2023-03-27	S2	9.25	9.49	1267.00	Curve	TRUE	R-Regular	PRO	LRG-31	10 medium
2023-03-27	S2	9.64	9.79	792.00	Curve	TRUE	R-Regular	PRO	LRG-31	10 medium
2023-03-27	S2	10.11	10.17	317.00	Tan.	TRUE	R-Regular	PRO	LRG-31	10 medium
2023-03-27	S2	10.51	10.79	1478.00	Curve	TRUE	R-Regular	PRO	LRG-31	10 medium
2023-03-27	S2	8.82	8.99	898.00	Curve	TRUE	R-Regular	PRO	LRG-31	10 medium
2023-03-27	S2	8.47	8.54	370.00	Tan.	TRUE	R-Regular	PRO	LRG-31	10 medium
2023-03-27	S2	10.17	10.51	1795.00	Curve	TRUE	R-Regular	PRO	LRG-31	10 medium
2023-03-27	S2	9.64	9.79	792.00	Curve	TRUE	R-Regular	PRO	LRG-31	10 medium
2023-03-27	S2	10.11	10.17	317.00	Tan.	TRUE	R-Regular	PRO	LRG-31	10 medium
2023-03-27	S2	9.49	9.64	792.00	Tan.	TRUE	R-Regular	PRO	LRG-31	10 medium
2023-03-27	S2	9.79	10.11	1690.00	Curve	TRUE	R-Regular	PRO	LRG-31	10 medium
2023-03-27	S2	9.49	9.64	792.00	Curve	TRUE	R-Regular	PRO	LRG-31	10 medium
2023-03-27	S2	9.79	10.11	1690.00	Curve	TRUE	R-Regular	PRO	LRG-31	10 medium
2023-03-27	S2	8.99	9.25	1373.00	Tan.	TRUE	R-Regular	PRO	LRG-31	10 medium
2023-03-27	S1	10.51	10.79	1478.00	Curve	TRUE	R-Regular	PRO	LRG-31	10 medium

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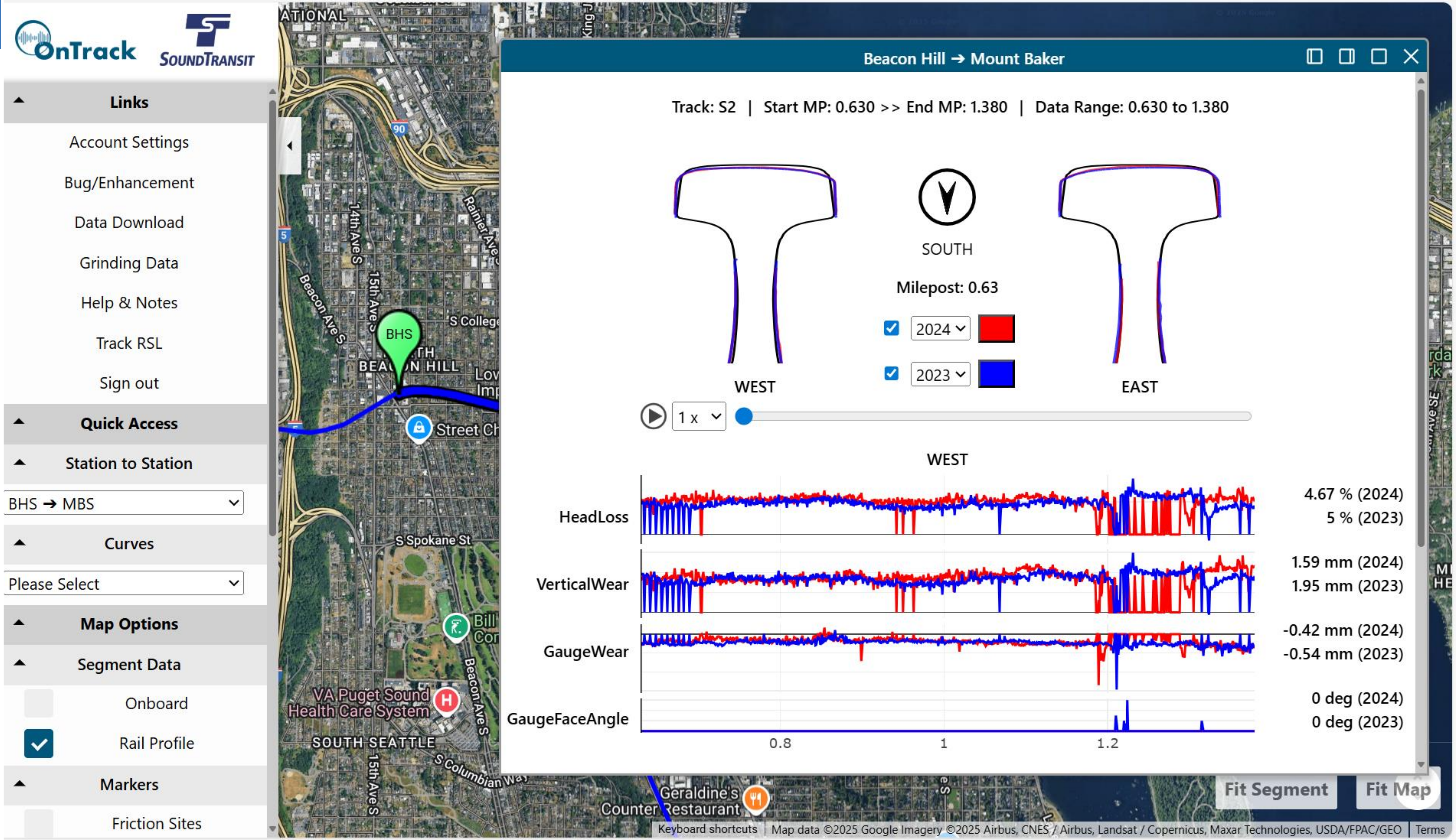
OnTrack Database: Rail Profile



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OnTrack Database: Remaining Service Life (RSL)

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Track Remaining Service Life

Date: Oct 2023

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Segment	Curve	Begin Milepost	End Milepost	Remaining Service Life (years)
RBS ➔ TUK	NB1002	6.150	6.380	13
CCS ➔ MBS	SB1612	2.530	2.700	19
WLS ➔ USS	NB1612	2.540	2.700	20
SEA ➔ TUK	SB514	0.110	0.870	20
TUK ➔ RBS	NB512	0.120	0.830	21
TUK ➔ SEA	SB1004	6.670	6.920	22
TUK ➔ SEA	NB1028b	9.990	10.080	22
ALS ➔ SEA	SB704	1.400	1.490	22
RBS ➔ TUK	SB1002	6.150	6.380	22
SEA ➔ ALS	NB2000a	10.890	11.000	23
OTS ➔ CCS	NB1640	1.360	1.420	23
ALS ➔ SEA	SB608	0.690	0.910	23
TUK ➔ SEA	NB1028a	9.790	9.990	24
TUK ➔ RBS	SB510	0.890	0.920	24
TUK ➔ RBS	NB610	1.000	1.100	24
TUK ➔ RBS	SB1644b	1.170	1.190	24
TUK ➔ RBS	NB604	0.240	0.430	24
TUK ➔ RBS	NB602	0.170	0.220	24
SEA ➔ ALS	SB1018	8.540	8.780	24
SOS ➔ STS	NB2030	12.200	12.320	24

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Virtual Rail: Digital Twin

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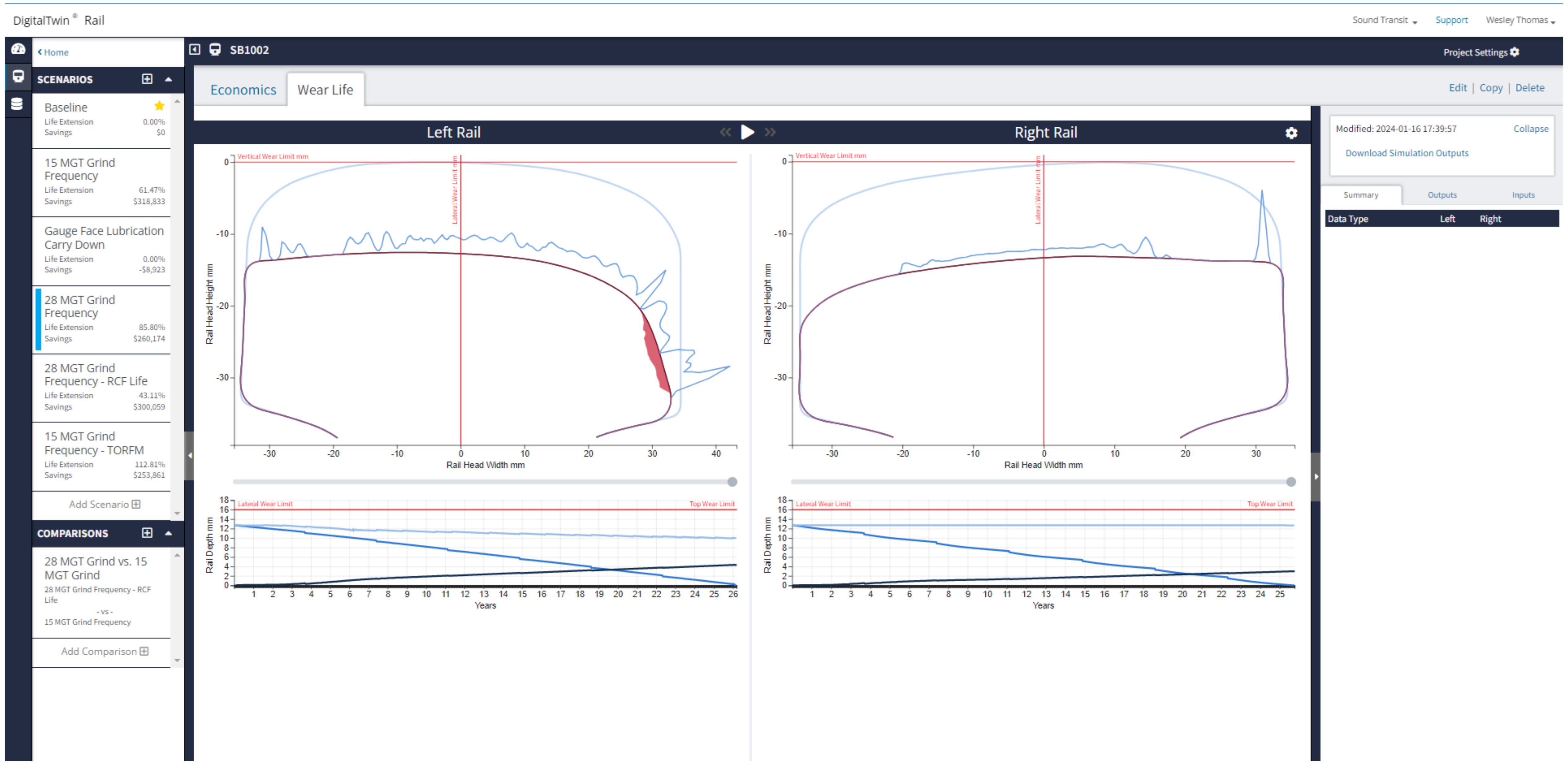
Rail Life Simulation

- Grinding Strategy
    - Rail Profile
    - Depth of Cut
    - Schedule
- Friction Management
- Rail Metallurgy
- Track Geometry
- Traffic and Wheels

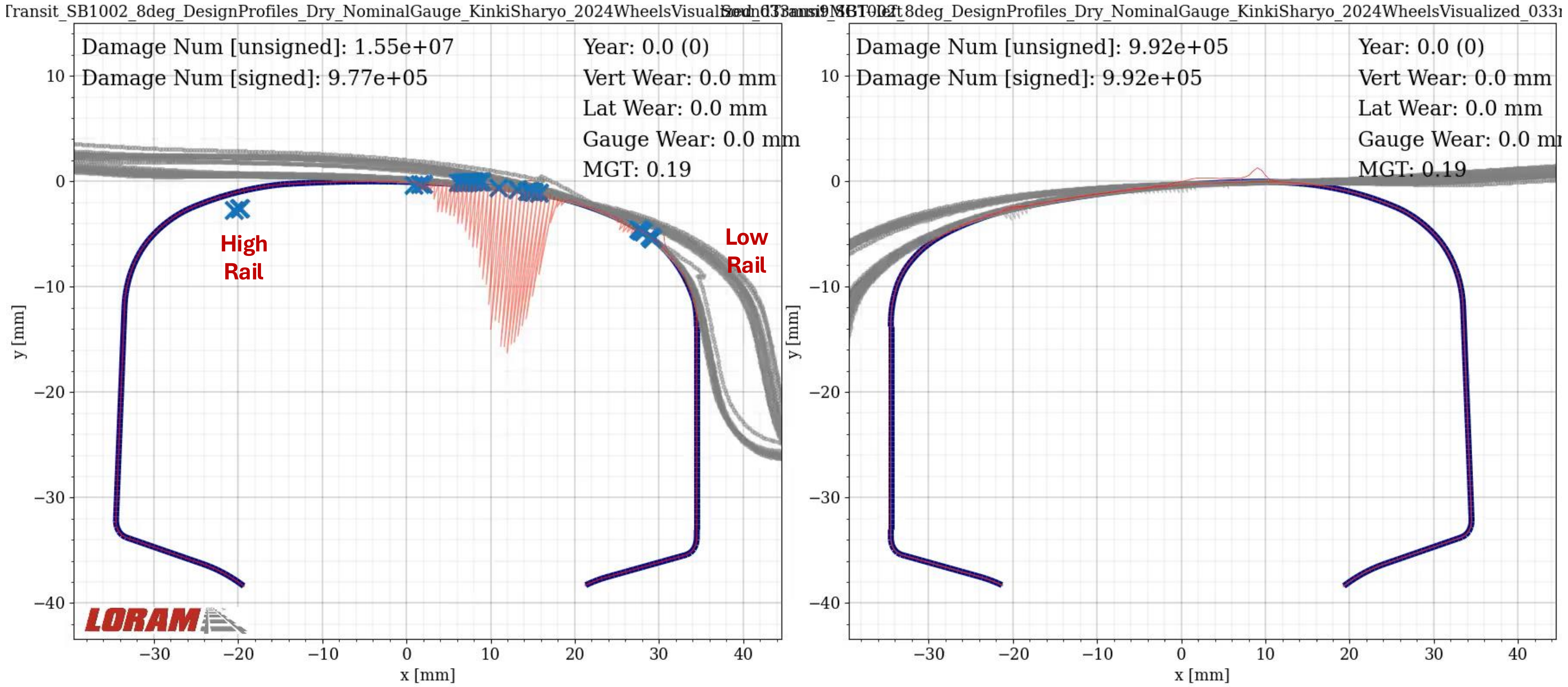


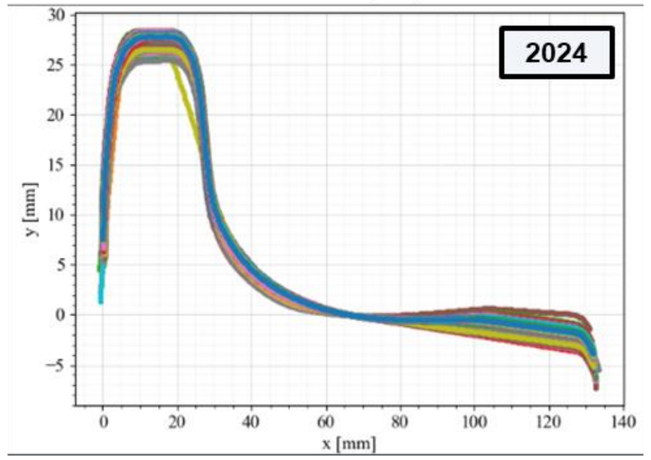
Virtual Rail: Digital Twin

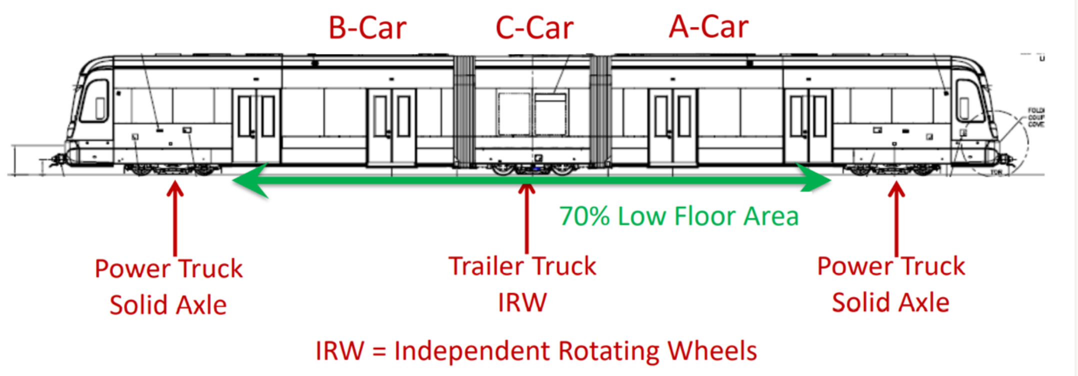
Rail Life Simulation

- Rail life simulation to better understand rail life and damage and optimize grinding.
- Calibrate DT model based on studs, wheel rail interaction and wear patterns that are unique to ST sites.
- Rail Maintenance Planning – Test different preventive maintenance strategies for rail life and budget.

After Two Iterations the Pilot Model Matches Well with Rail Wear, Contact Bands and RCF Damage Risk After Vehicle/Wheel Data







Upcoming Unique Challenges

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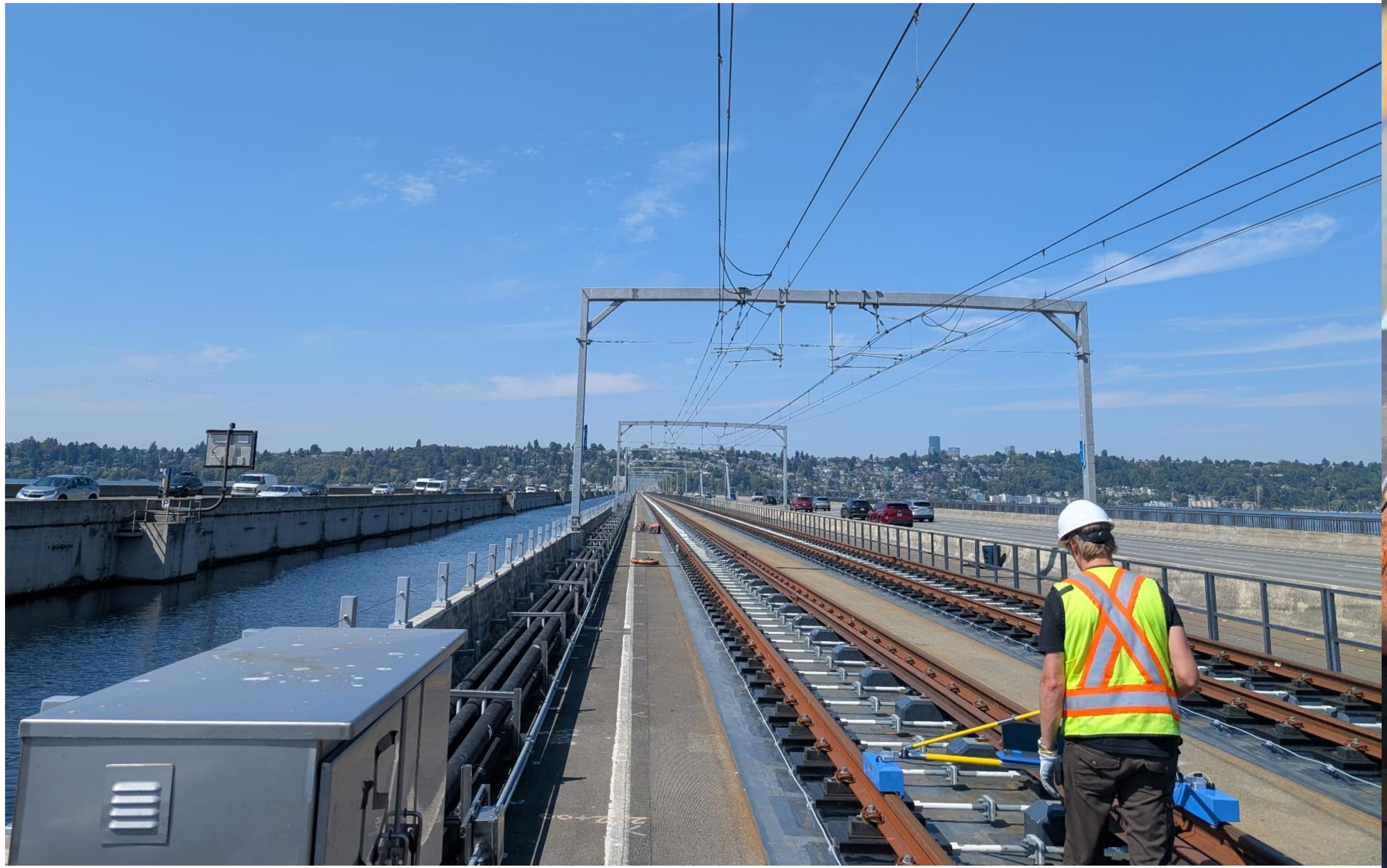
I-90 Floating Bridge



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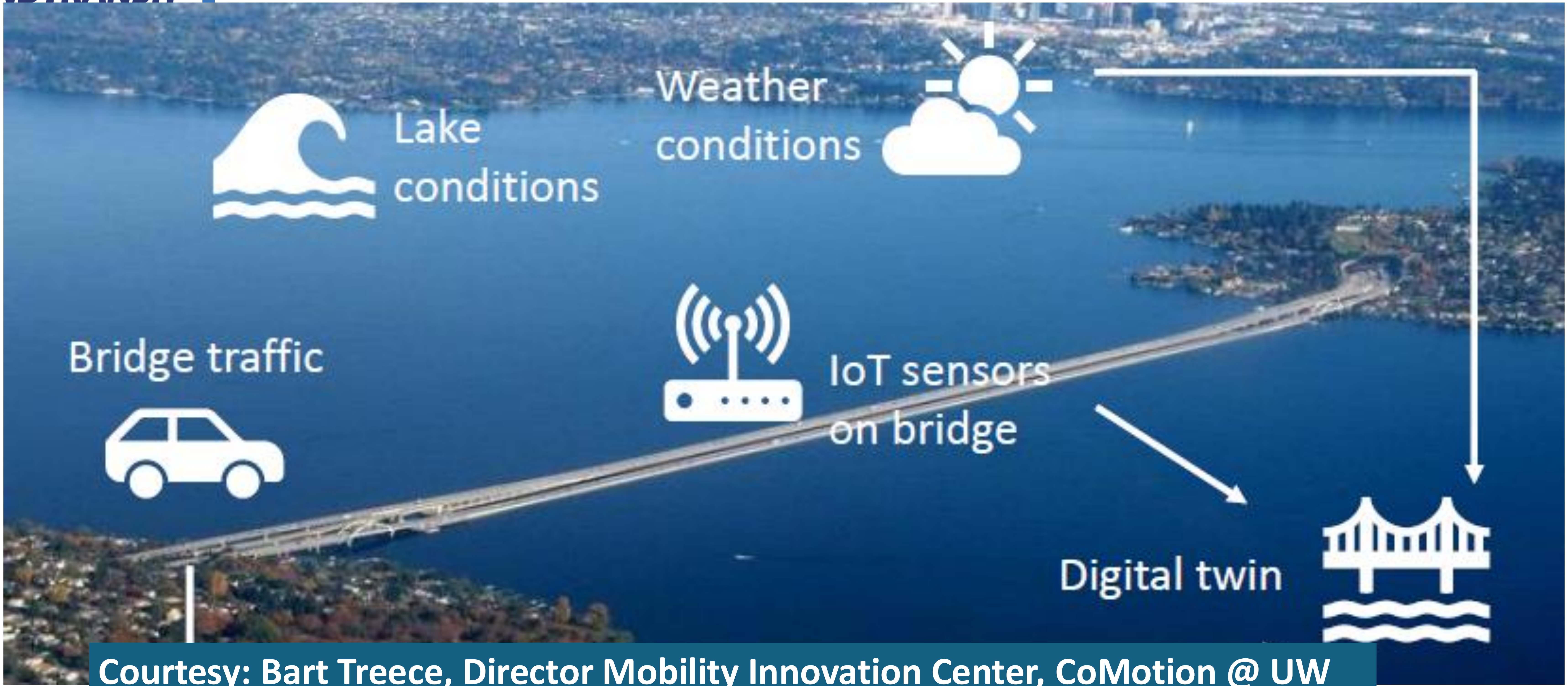
I-90 Bridge Monitoring by WSDOT (UW Project)



Courtesy: Bart Treece, Director Mobility Innovation Center, CoMotion @ UW

Conclusion

- Proactive wheel rail interface management is critical to maximize asset life, minimize unplanned repair, and manage noise and vibration levels.
- Refine rail grinding specification for routine maintenance grind to 1-step process using one type of stone to improve economic and schedule efficiencies.
- Consider how to improve post-grind cleaning. Consider periodic maintenance rail cleaning, especially on rails with lubrication.
- Improve thermite/field rail welding procedures with emphasis on quality control.
- Consider investigating rail head hardness and using less hard rail in the future.
- Develop an understanding of the relation between traction power and areas with rail studs.
- Focus on how to consolidate asset data and futureproof for predictive maintenance.