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RIDE QUALITY ASSESSMENT USING PROBE VEHICLE ACCELERATION MEASUREMENTS

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Probe Vehicle Concept

Fleet of on-road vehicles collect road data in real-time.

Could include a fleet of instrumented vehicles or integrated production models used by normal drivers.

Probe Vehicle Potential Benefits

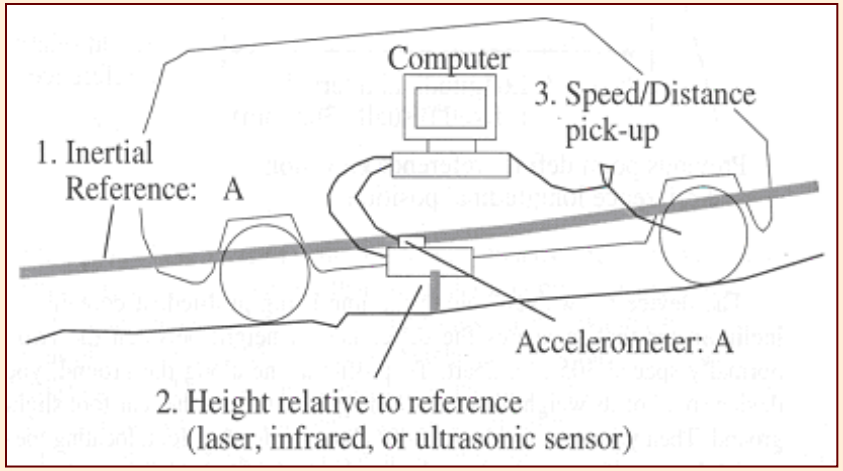
- ☑ **Wider coverage on networks**
- ☑ **Low cost per unit of data**
- ☑ **Continuous and automated data collection**
- ☑ **No traffic disruptions**
- ☑ **Better representation of actual driver perception**

Experiment

- ☑ Acceleration measurements taken from a Ford Fusion and a Volvo Truck.
- ☑ Profile data taken from a laser-profiler on the Virginia Smart Road.
- ☑ Acceleration and profile data repeatability
- ☑ Effect of test speed on vehicle vertical acceleration
- ☑ Effect of vehicle type on vehicle vertical acceleration
- ☑ Identification of rough spots

Evaluating Ride Quality

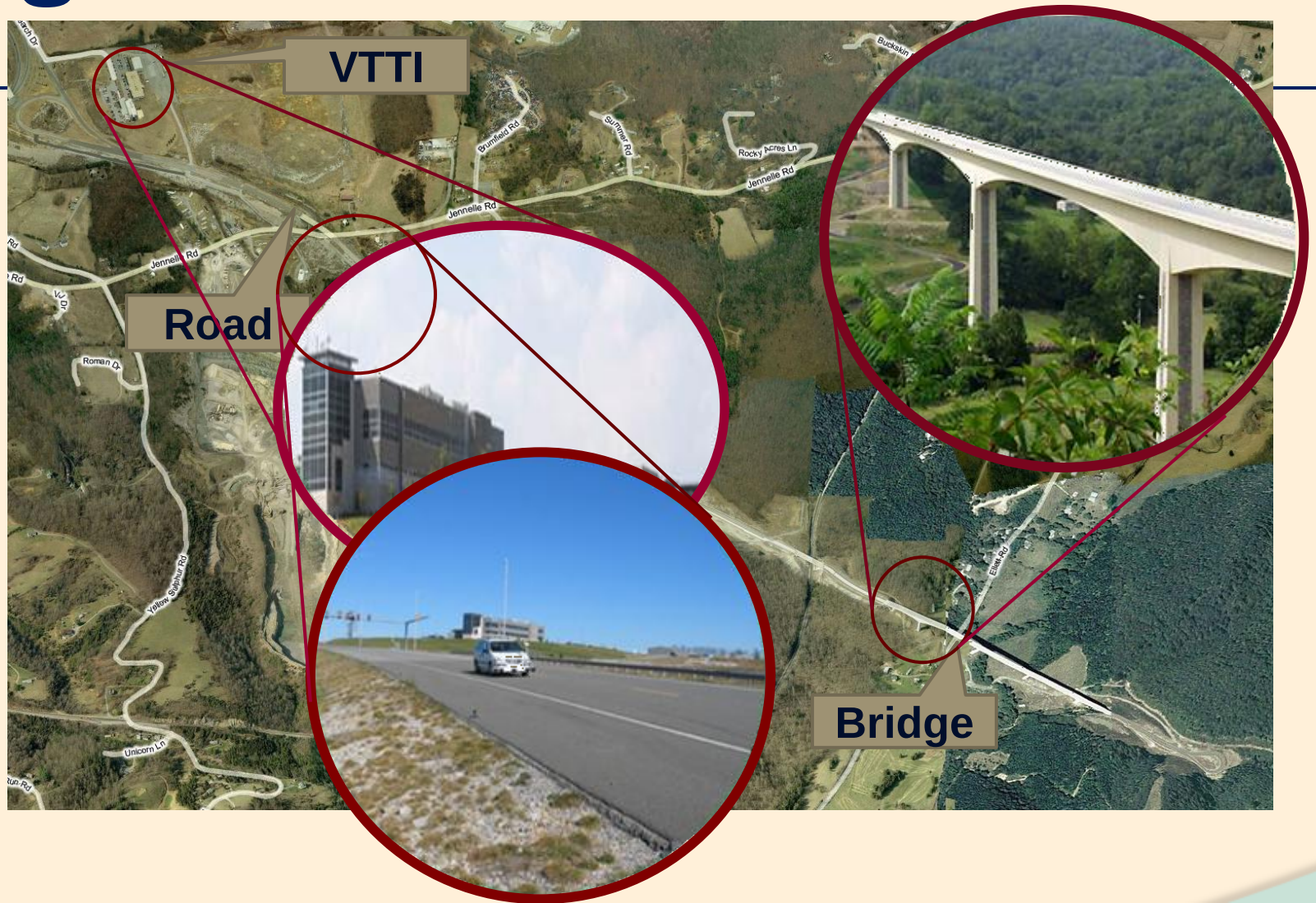
- ☑ **Typically referred to as smoothness or roughness.**
- ☑ **Computed by measuring vertical deviations in surface.**
- ☑ **Measured by high speed laser profilers.**
- ☑ **Quantified using the International Roughness Index**



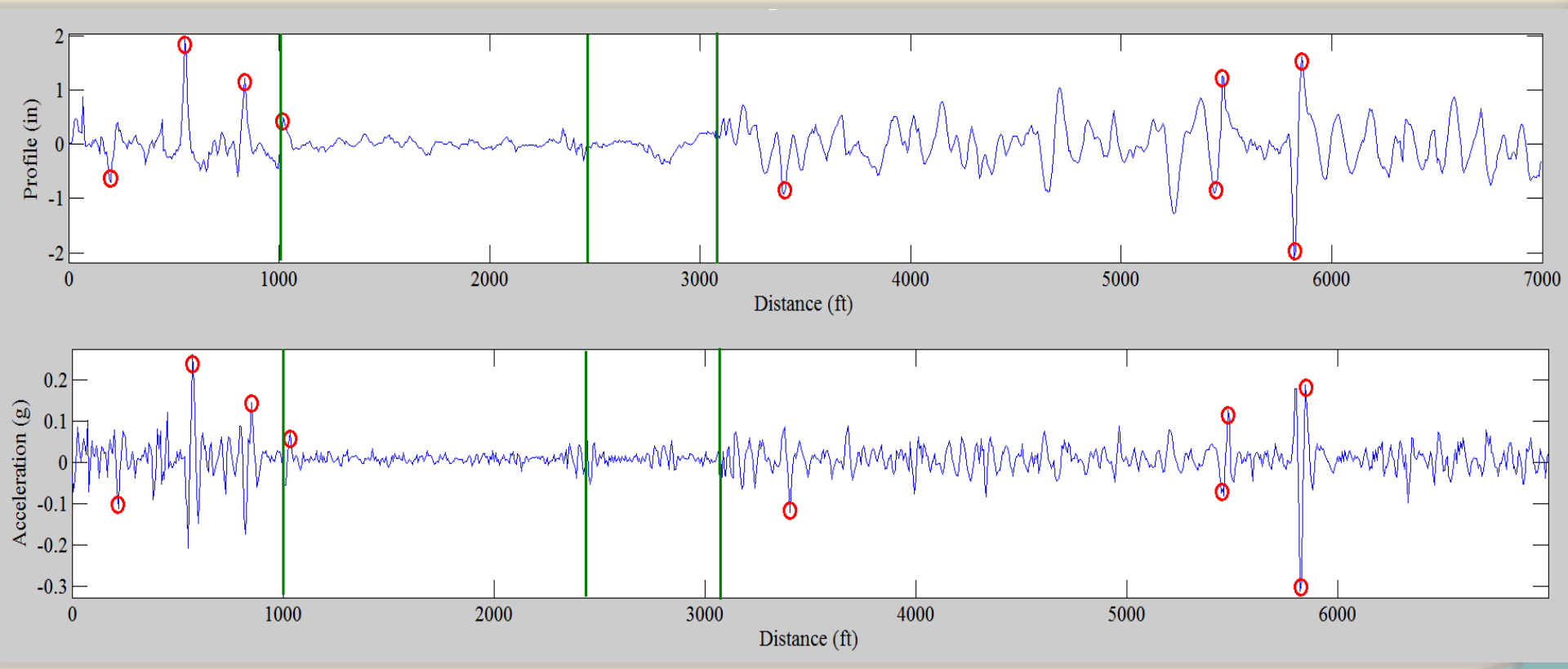
Relation to Acceleration

- ☑ **Road profile measures vertical variations in pavement.**
- ☑ **These variations are experience by vehicle.**
- ☑ **Vehicle accelerometers can document these changes.**
- ☑ **Bumpy areas of pavement display larger accelerations.**

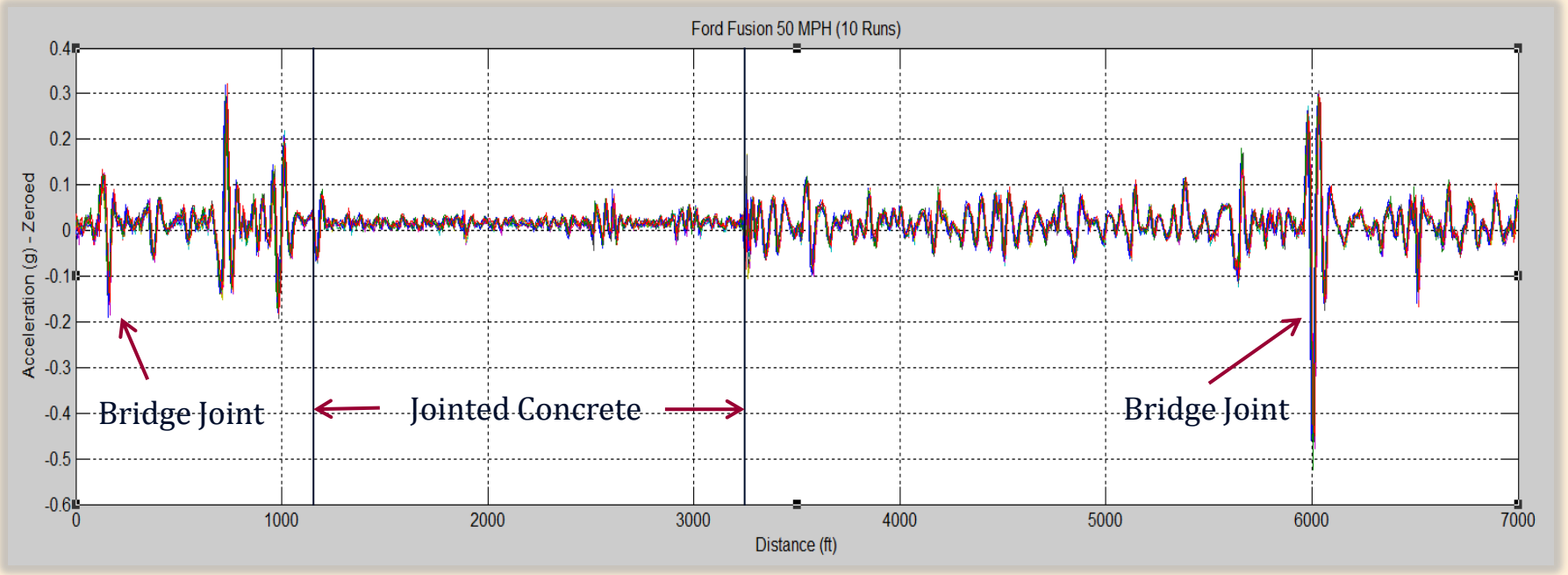
Virginia Smart Road



Smoothness Comparison



Repeatability (Ford Fusion)

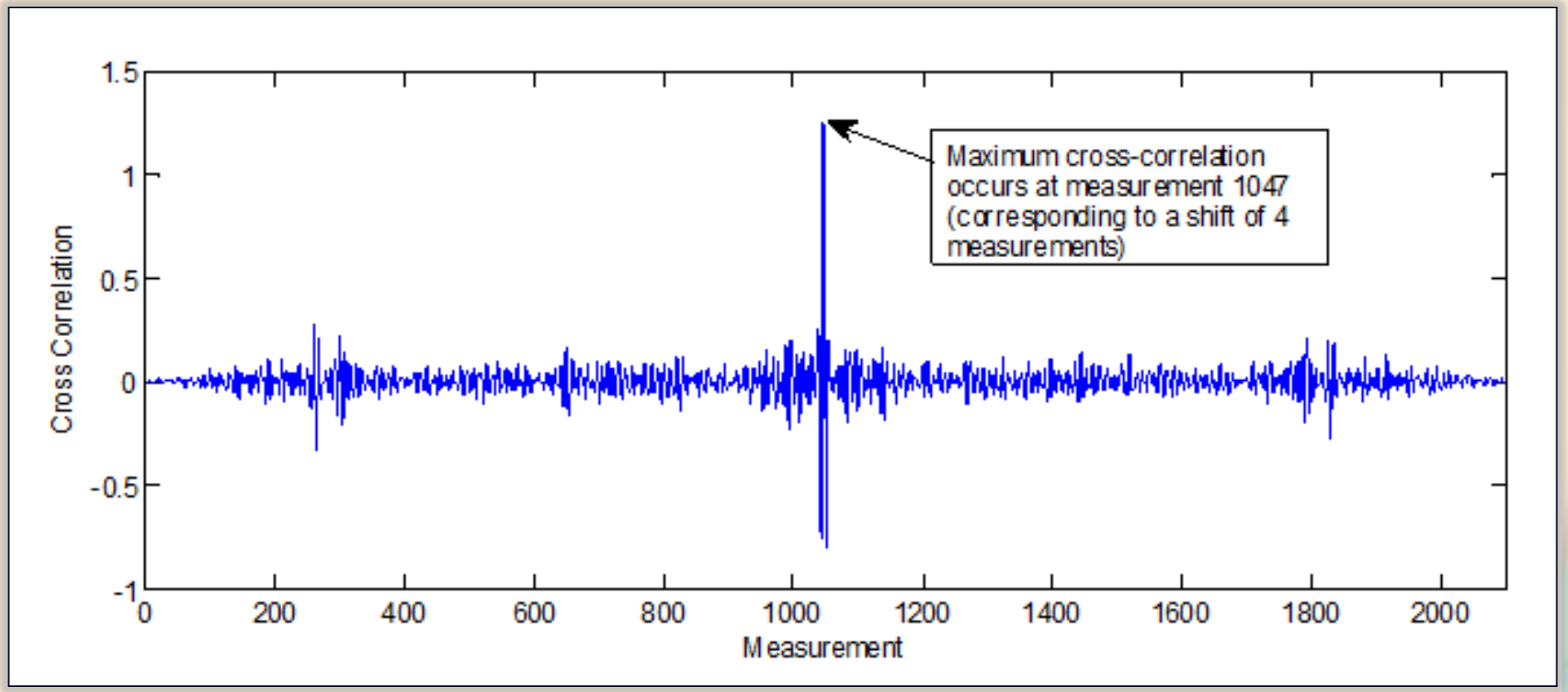


Cross-Correlation

- ☑ **Used to verify the similarity of two waveforms.**
- ☑ **Amount of shifting that optimizes the cross-correlation is utilized to more accurately match waveforms.**

$$\varphi_{xy}(m) = E[x_n y_{n+m}] = \lim_{L\to\infty} \frac{1}{L} \sum_{n=0}^{L-1} x_n y_{n+m};$$

Cross-Correlation

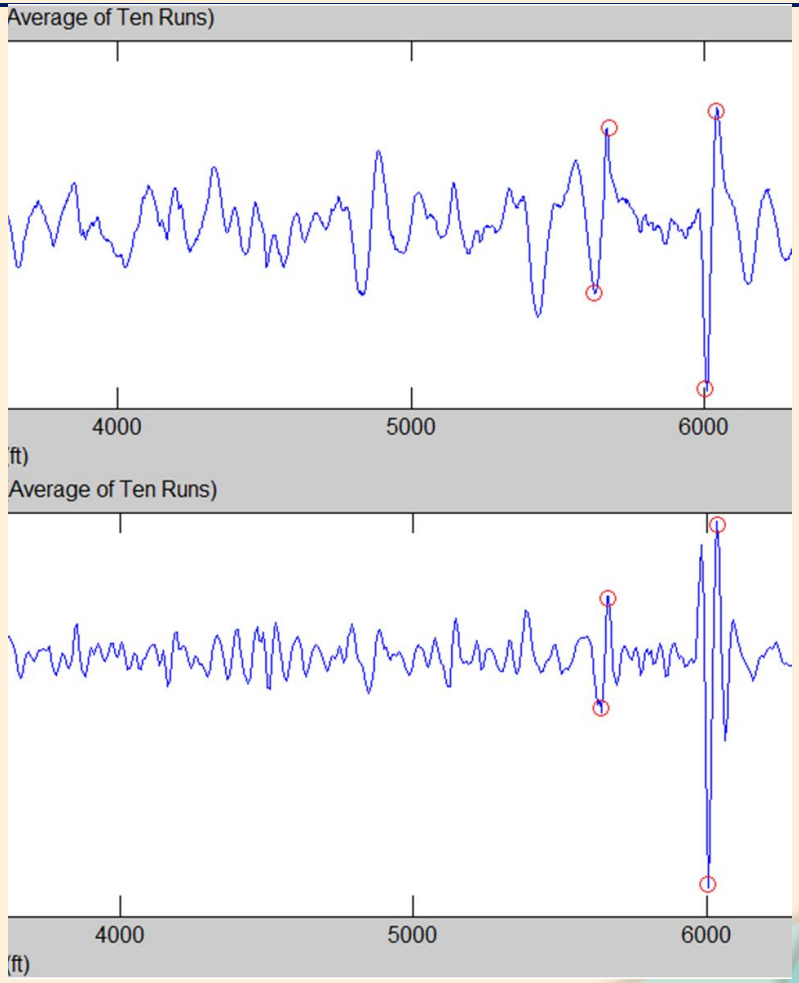


Acceleration Repeatability

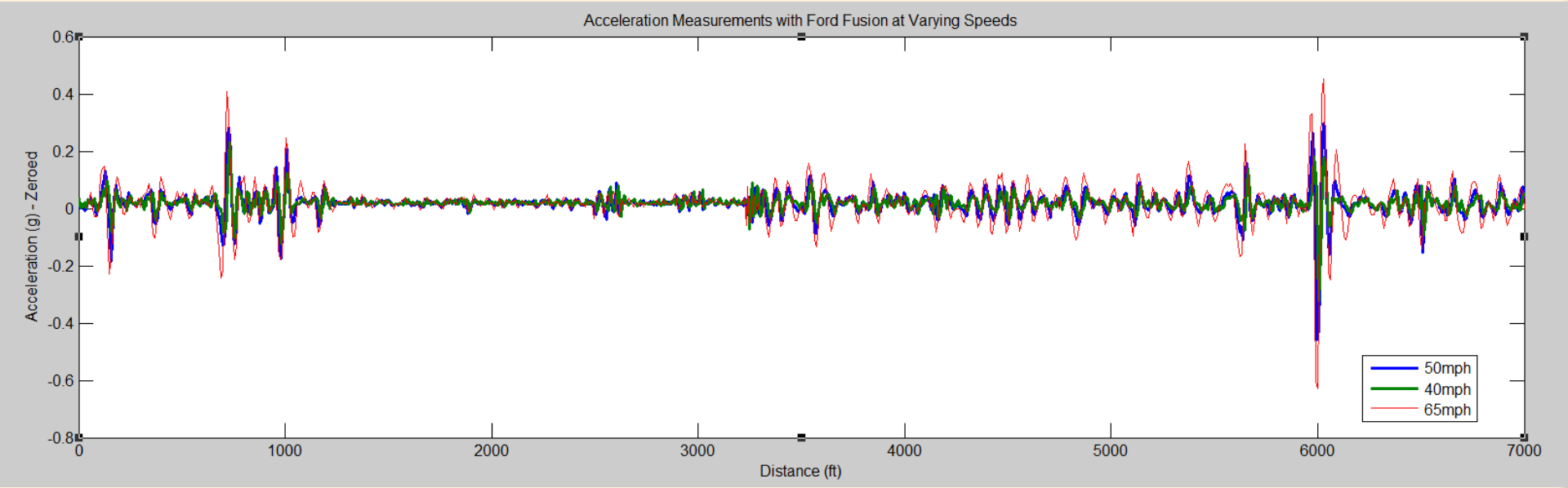
Measurement Type	Test Runs Compared	Value (g)
Standard Deviation of Differences	Runs 1 and 3	0.0244
Standard Deviation of Differences	Runs 2 and 3	0.0206
Standard Deviation of Differences	Runs 4 and 3	0.0224
Variance of Differences	Runs 1 and 3	0.00053984
Variance of Differences	Runs 2 and 3	0.00042248
Variance of Differences	Runs 4 and 3	0.00050327

Signal to Noise Ratio

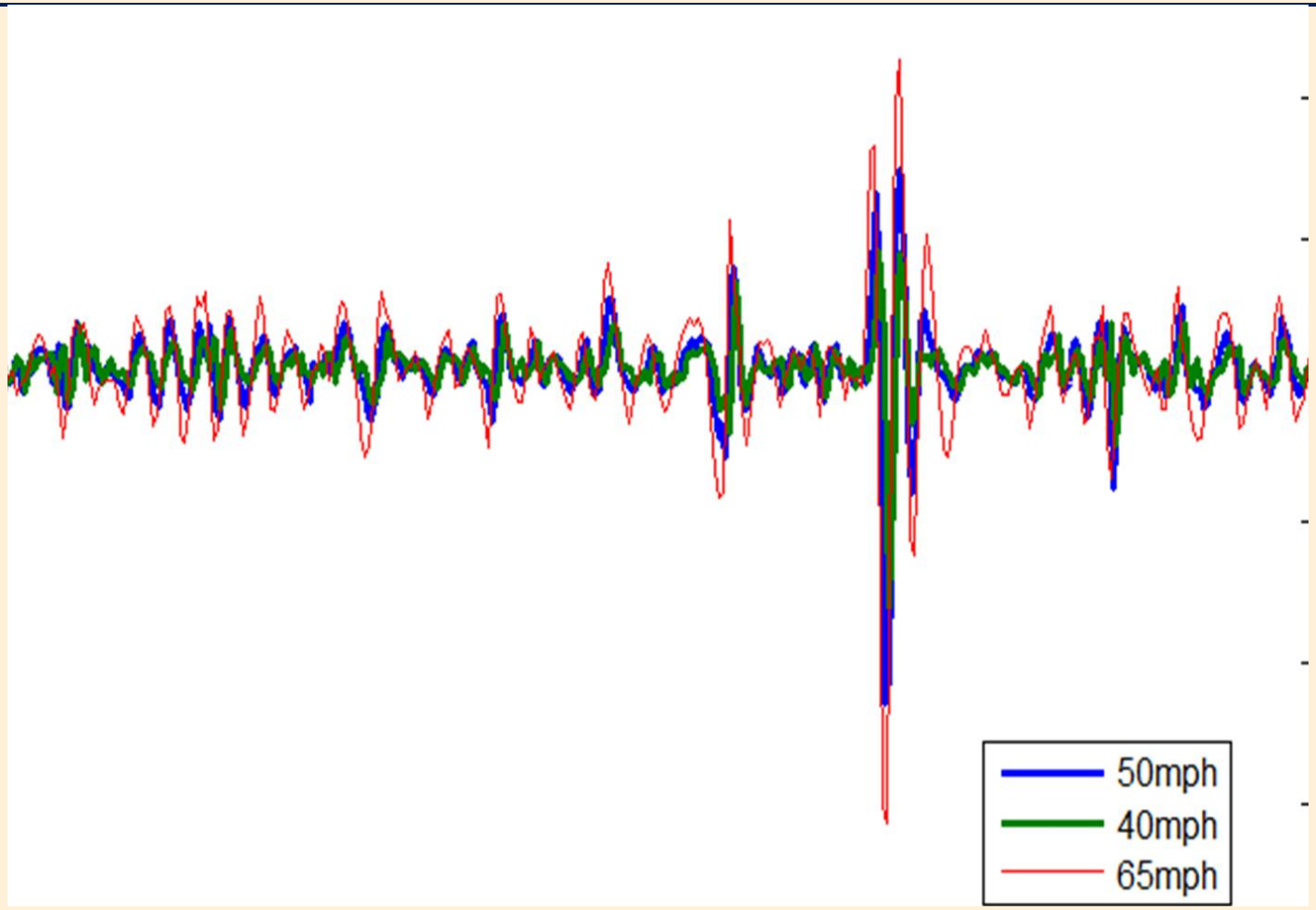
- ☑ **Std of Measurements divided by std of the difference between 2 measurements**
  - ☑ **Ford Fusion: 1.73**
  - ☑ **Profiler: 1.16**
  - ☑ **Volvo Truck: 0.73**
- ☑ **Quality of measurement**



Effect of Speed



Effect of Speed



Effect of Speed

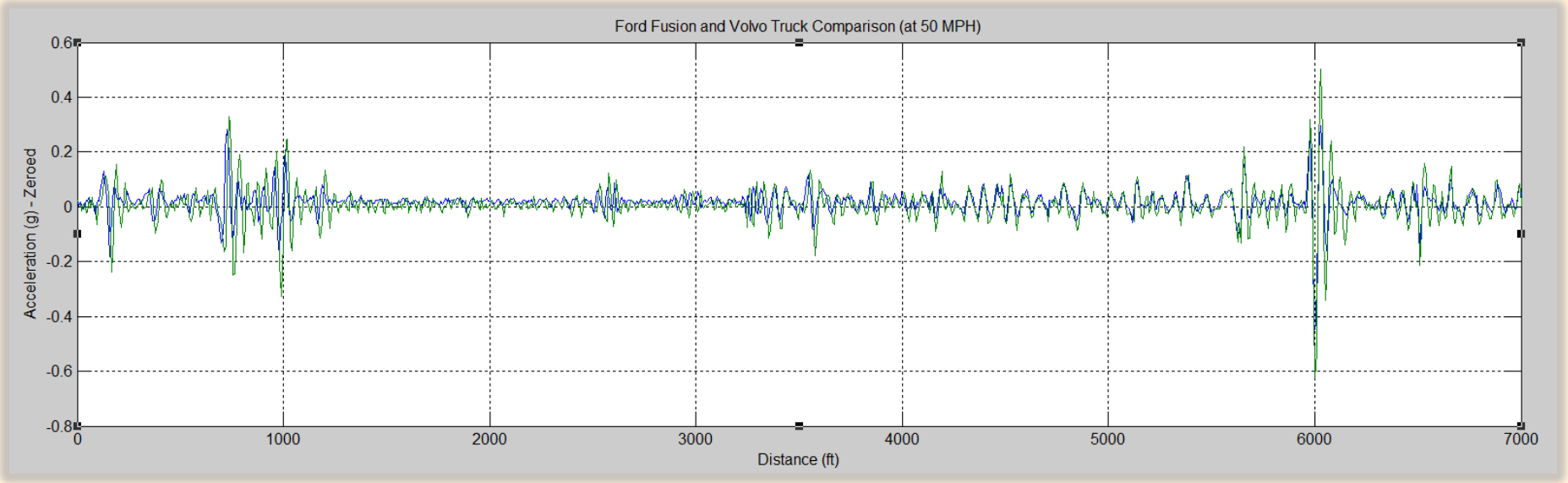
- ☑ **10-90th Percentile Ranges**
  - ☑ **40 MPH = 0.0551 g**
  - ☑ **50 MPH = 0.0783 g**
  - ☑ **65 MPH = 0.1340 g**

- ☑ **Average Acceleration**
  - ☑ **40 MPH = 0.0258 g**
  - ☑ **50 MPH = 0.0296 g**
  - ☑ **65 MPH = 0.0474 g**

14.7% increase

60.1% increase

Effect of Vehicle Type



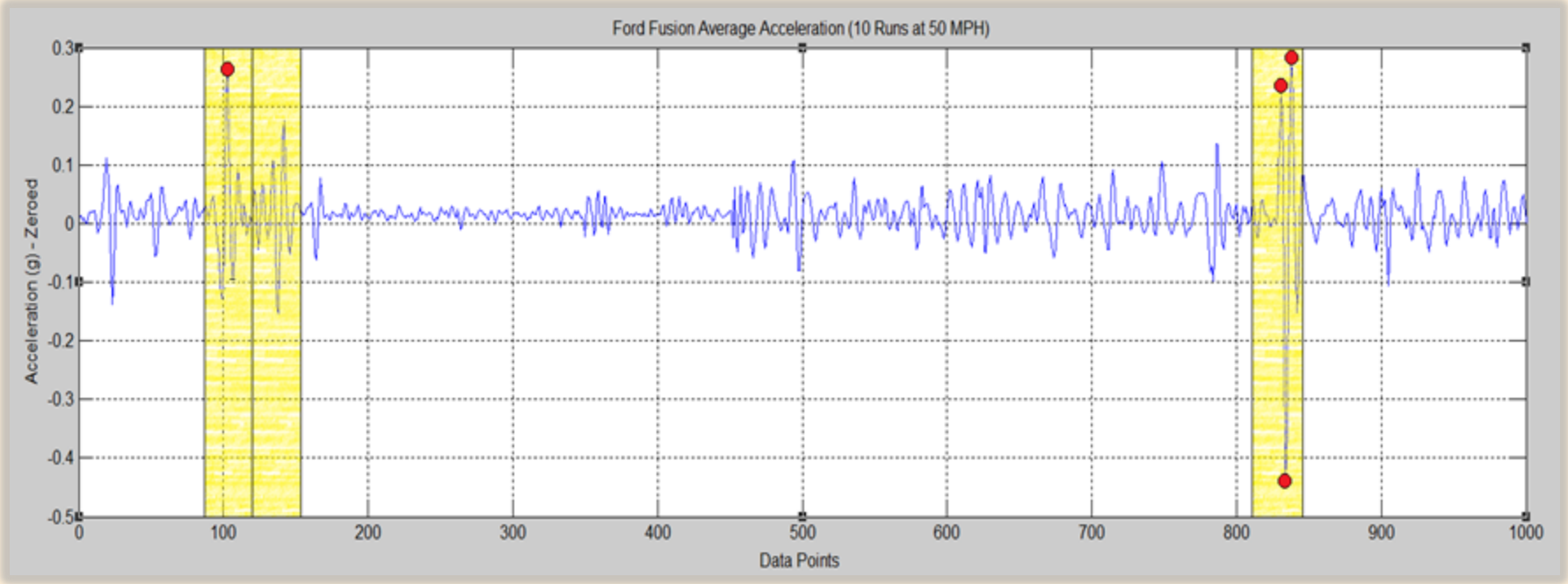
Effect of Vehicle Type

Effect of Vehicle Type

- ☑ **10-90th Percentile Ranges (at 50 MPH)**
  - ☑ **Ford Fusion = 0.0783 g**
  - ☑ **Volvo Truck = 0.1189 g**
- ☑ **Average Acceleration (at 50 MPH)**
  - ☑ **Ford Fusion = 0.0319 g**
  - ☑ **Volvo Truck = 0.0478 g**

Acceleration Analysis

Maintenance strategies can tailor roughness thresholds to meet needs by section or spot location.



Conclusions

- ☑ Ride quality (smoothness) is a promising application of probe vehicles.
- ☑ Acceleration measurements exhibit an acceptable level of repeatability.
- ☑ Acceleration is sensitive to vehicle speed, type.
- ☑ Rough sections of pavement can be identified using threshold values.

Questions?