3D Laser Imaging for Pavement Survey at 60 mph and True 1mm Resolution

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First Gen Vehicle's Exterior

Telescoped Camera and Four Strobe Lights

EXIT 81
Pleasant Grove
Road
1 MILE
ROAD
TEST
53071
ZKY 741
CHEVROLET

Second Generation DHDV

DIESEL
DG3E
3000W
BALDOR
WAYLINK
WAYLINK

Common Problems

- Poor Distress Field Data
  - Particularly Cracking
- Operating 3D Profile Line Rate
  - From 4000, 6000, to 8000/sec
  - About 4mm to 6mm (¼-inch) Resolution in the Longitudinal Direction at 60MPH (100KM/H)
  - Good Enough for Some Purposes; Not Sufficient

PaveVision3D Ultra Approach

- Use Multiple Sensors
- Increase 3D Profile Line Rate to 30,000/second
- Complete Coverage of Pavement Lane
  - True 1mm at Any Data Collection Speed up to 60MPH (100KM/H)

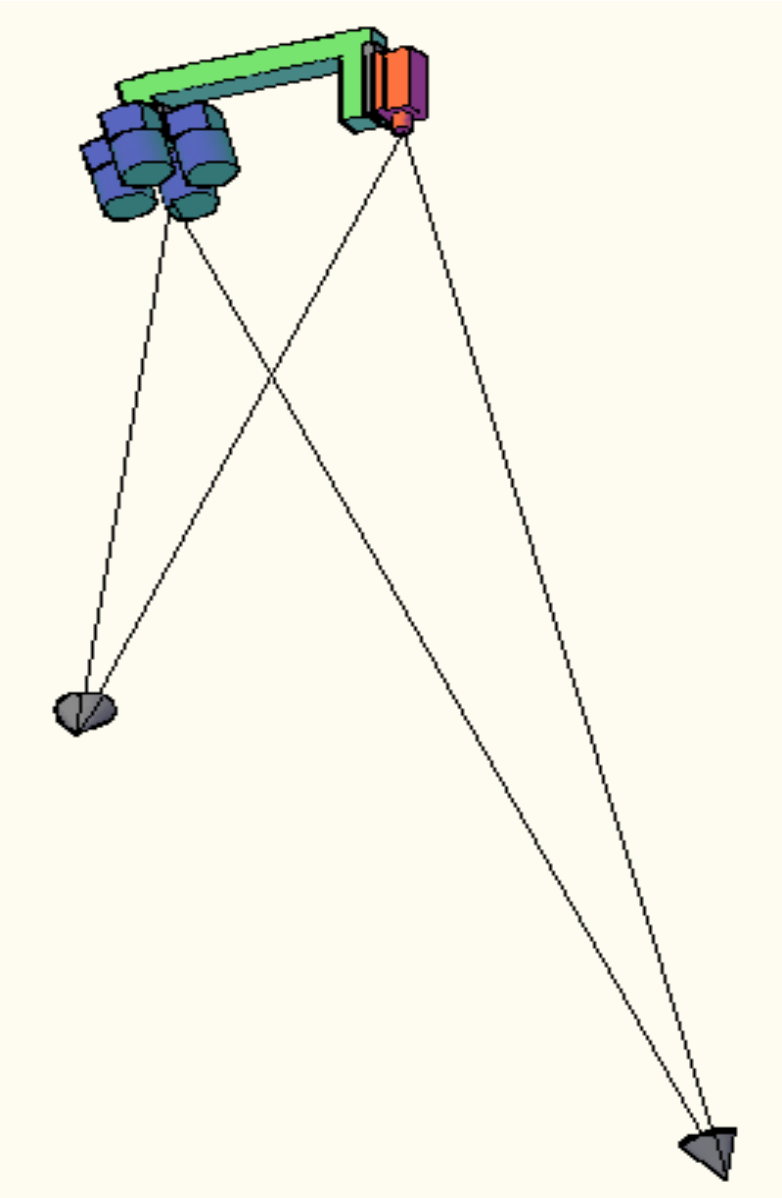
Data Rate & Power at 60MPH

- Single Computer
- Data Rate for 3D Only
  - 4000x2x28000=224,000,000 bytes, 224 MB/sec before compression
  - Continuous for a few hours non-stop
- Advantage
  - Low Power < 1000 watts in all
  - Complete Coverage at True 1mm

Data Compression & Management

- Raw Data from All Sensors
  - Over 10GB per Mile at 60MPH (100KM/H)
- 2D Compression: JPG/JPG2000
- 3D Compression
  - Proprietary Compression: over 10:1
- Production Data to Computer Storage: 1GB per Mile
- Relational Database Driven

PaveVision3D Ultra Design



PaveVision3D Ultra

PaveVision3D Ultra

PaveVision3D Ultra

Virtual Pavement

- 1mm Pavement Surface in All Three Dimensions
- High-Precision IMU
  - Grades
  - Horizontal Curves
  - Cross-Slope

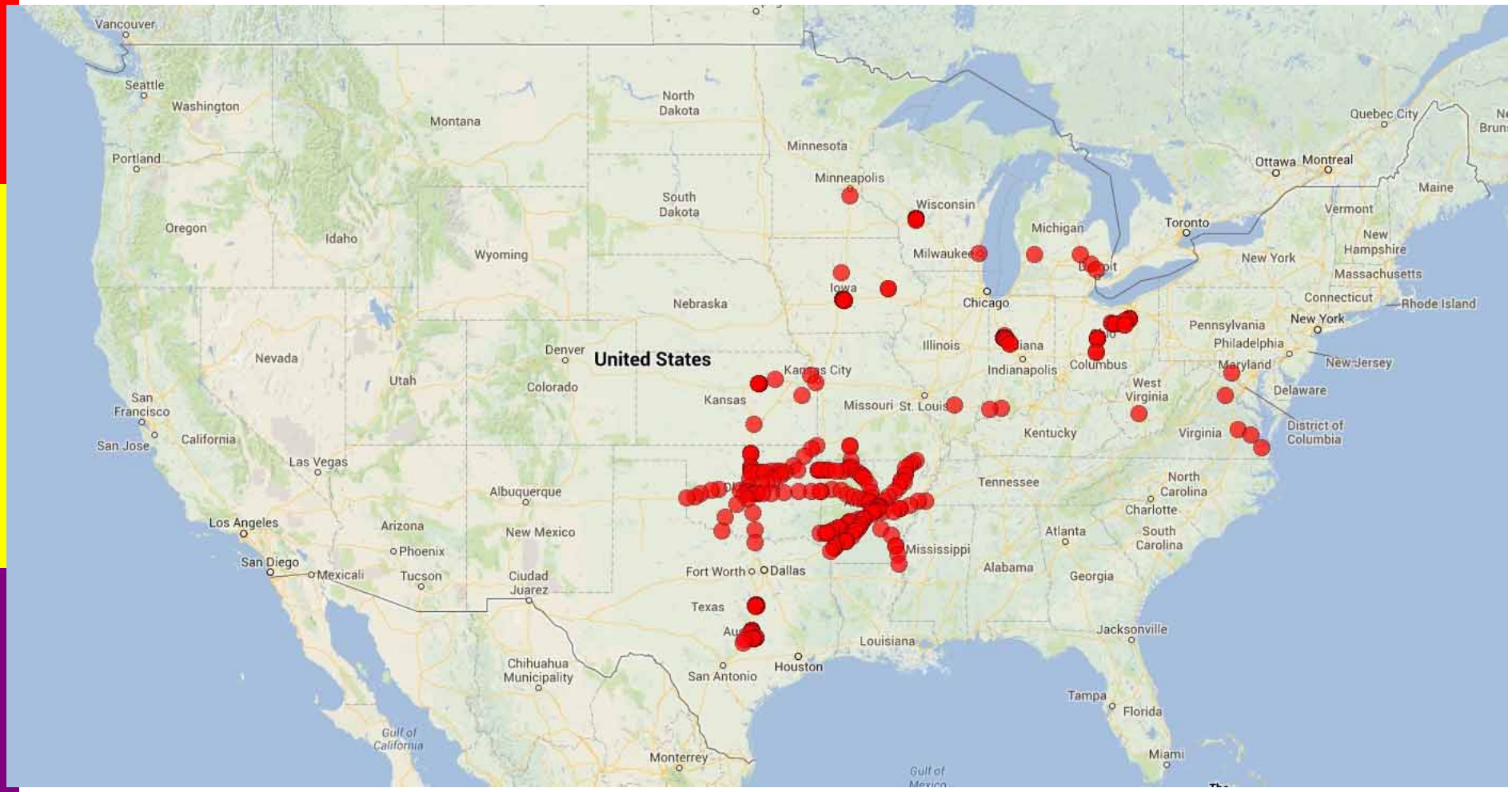
PaveVision3D Ultra Applications

- Now
  - Cracking, Rutting, IRI, Macro-Texture (MPD, MTD)
  - Safety Analysis: High-Friction, Rumble Strips, Hydroplaning/Grooving
  - Virtual Surface for Visualization
- In Progress
  - Longitudinal Profiling
  - Comprehensive Evaluation of Distresses
  - Comprehensive Performance Metric

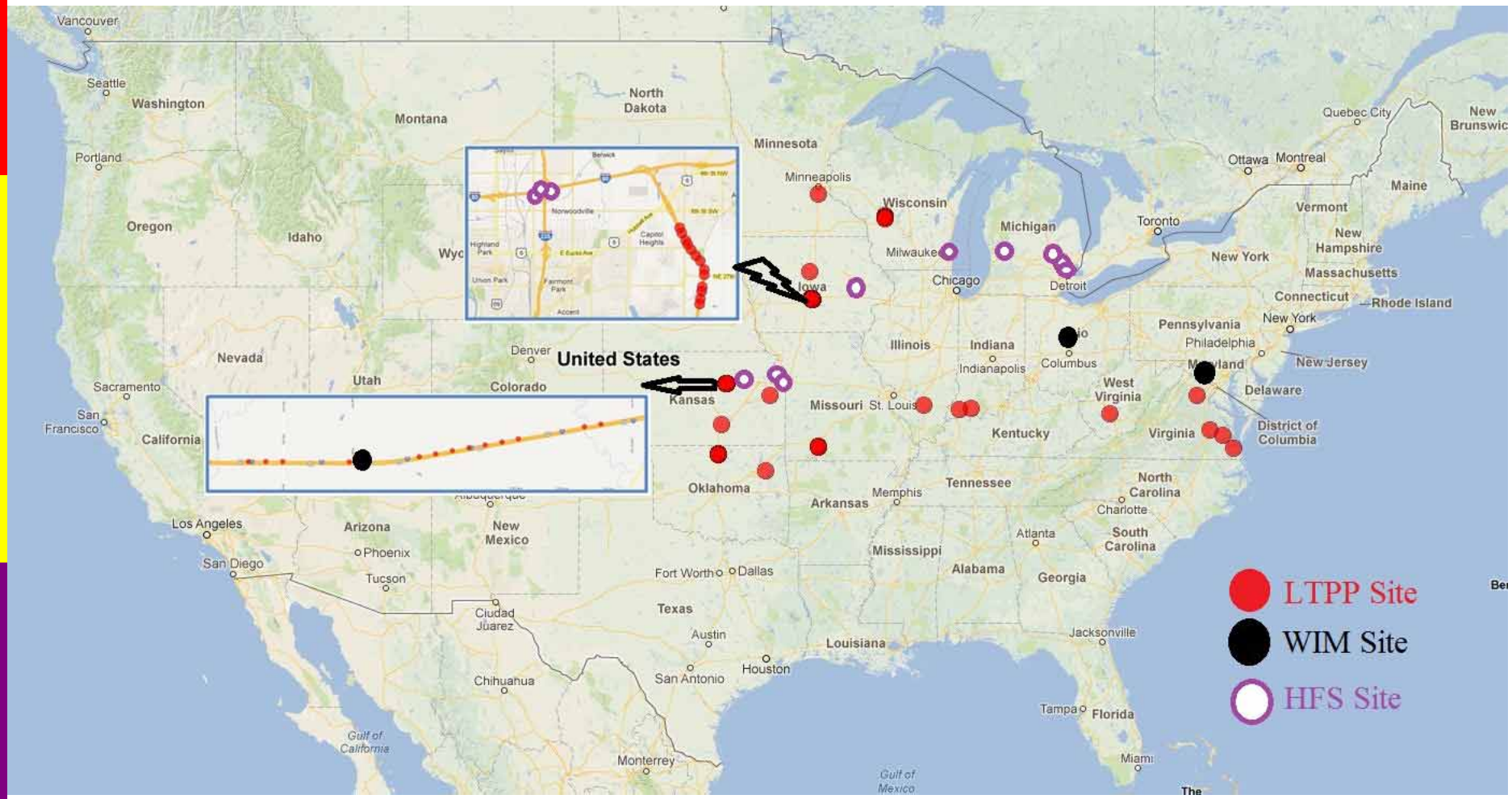
Example Projects / Applications

- Arkansas Highway Network
- Oklahoma Interstate Network
- INDOT
- TxDOT Project 6663 Phase II
- Ohio DOT
- LTPP Sites, Including Those with WIM
- High Friction Surface
- Next Generation Concrete Surface (NGCS)

Example Projects / Applications

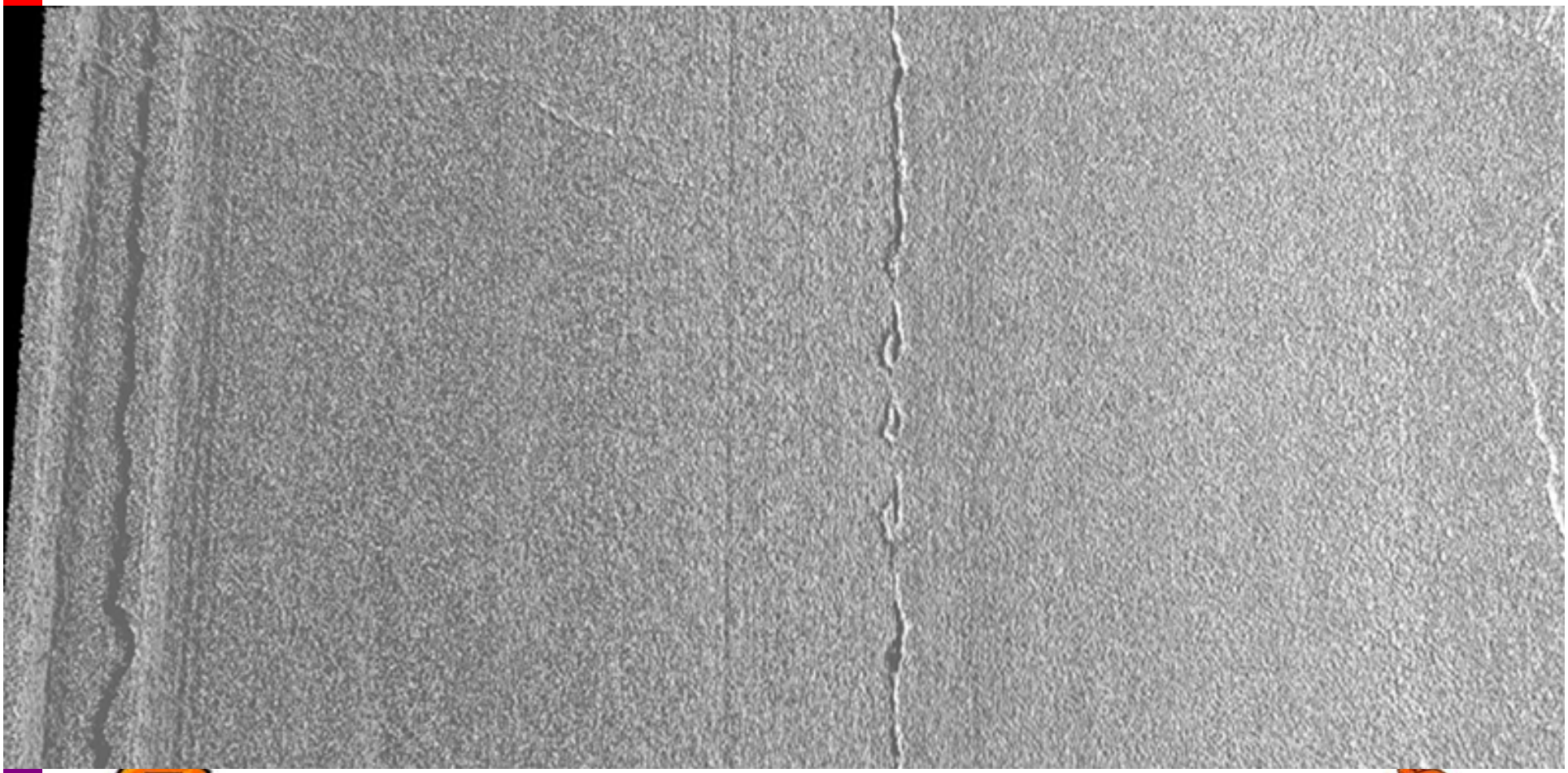


LTPP Data Collection



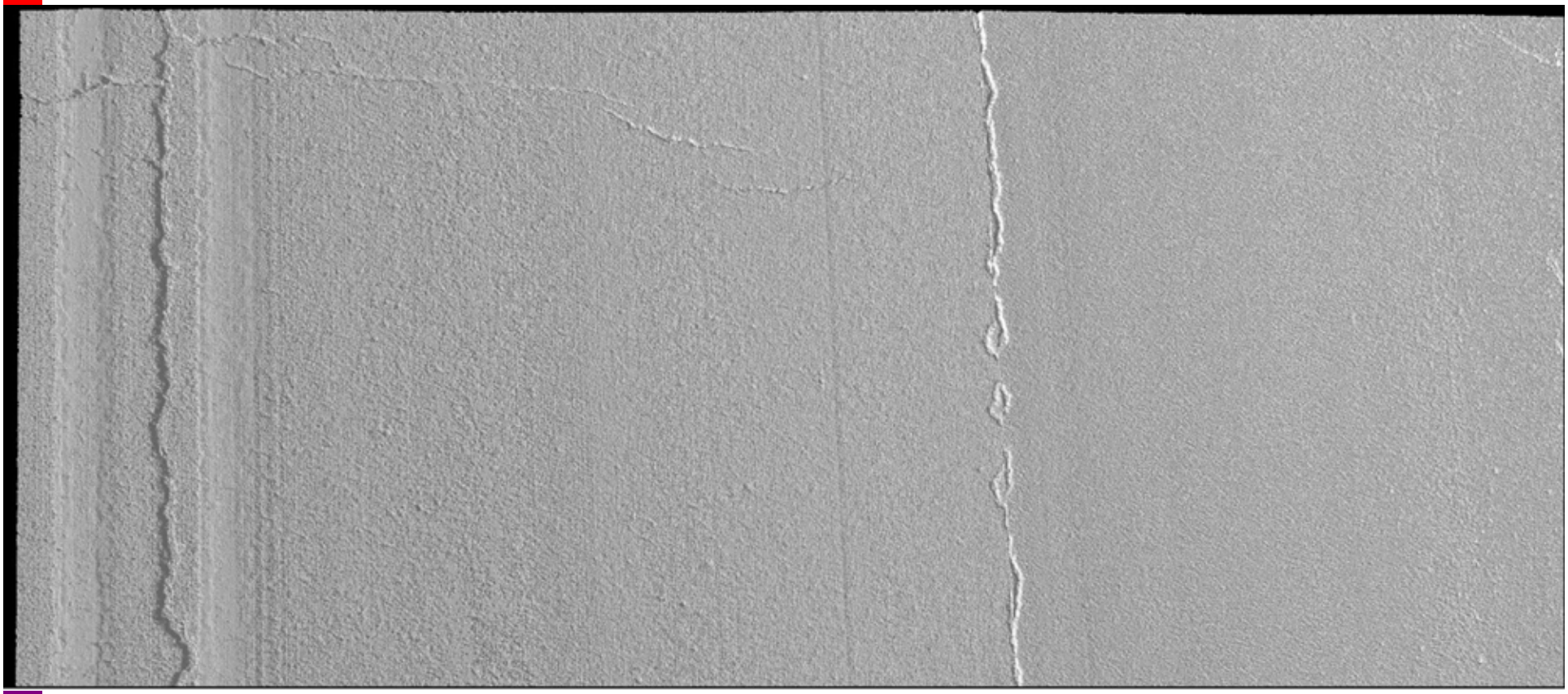
Comparison on the Same Pavement

- 7000 3D Profiles/Sec

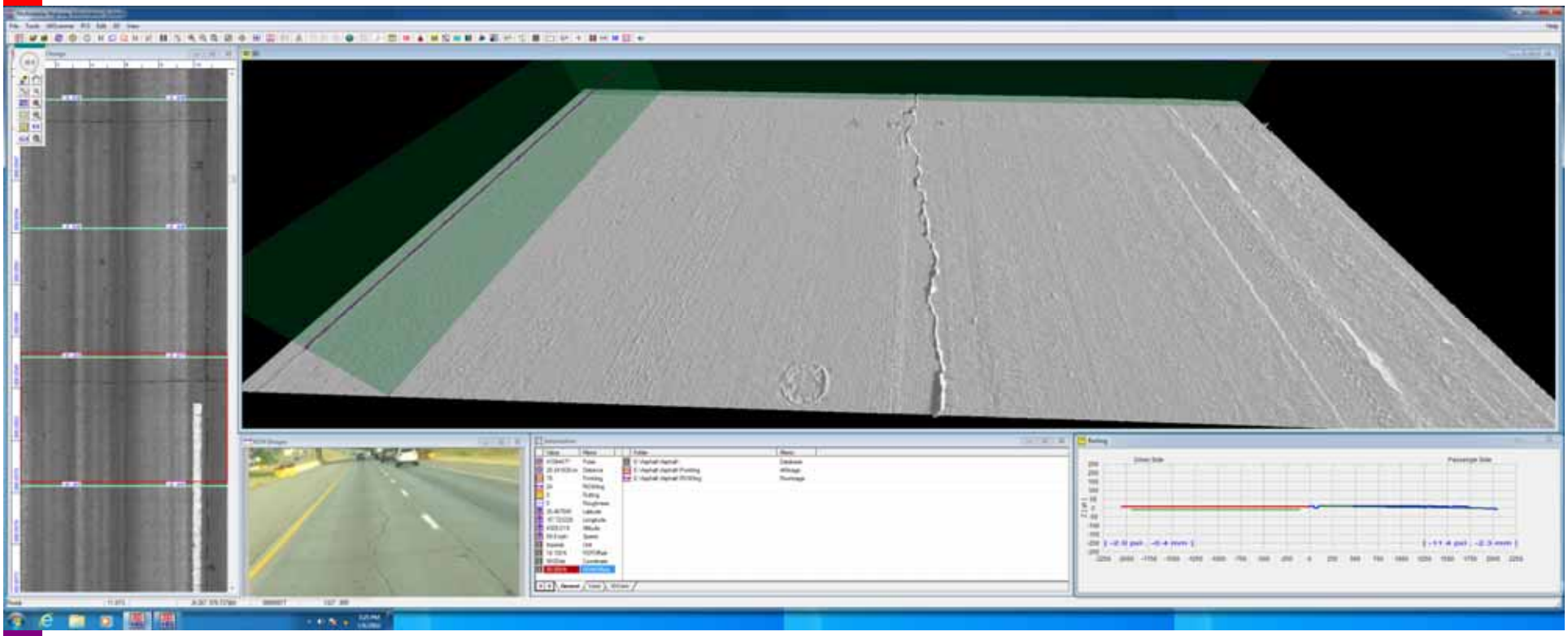


Comparison on the Same Pavement

- 28,000 3D Profiles/Sec



3D Data at 60MPH (100KM/h)



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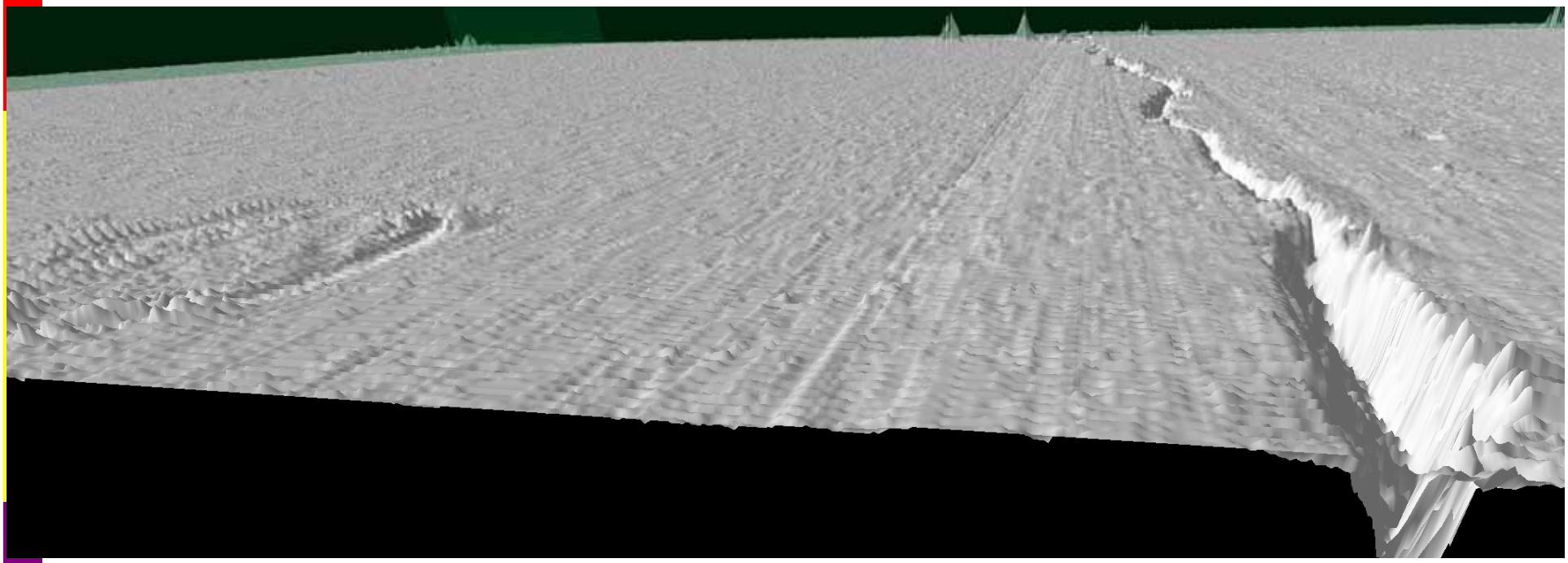

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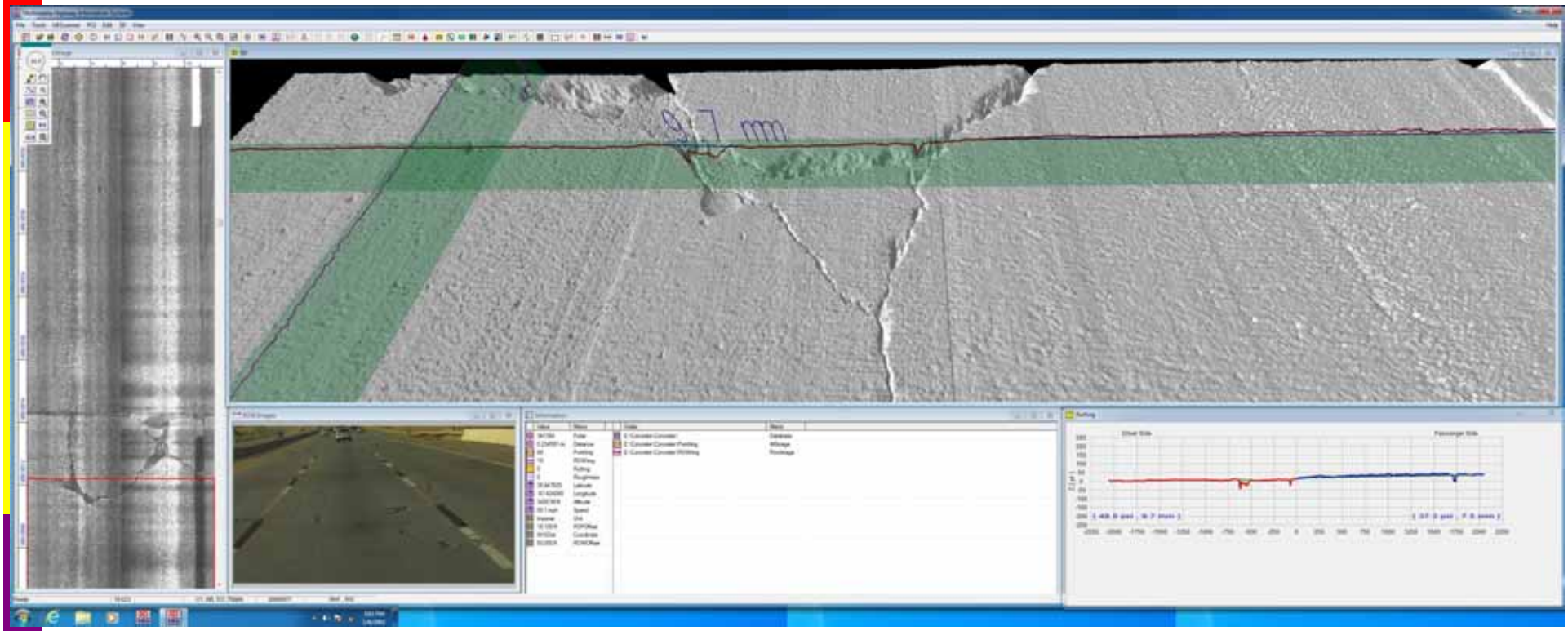

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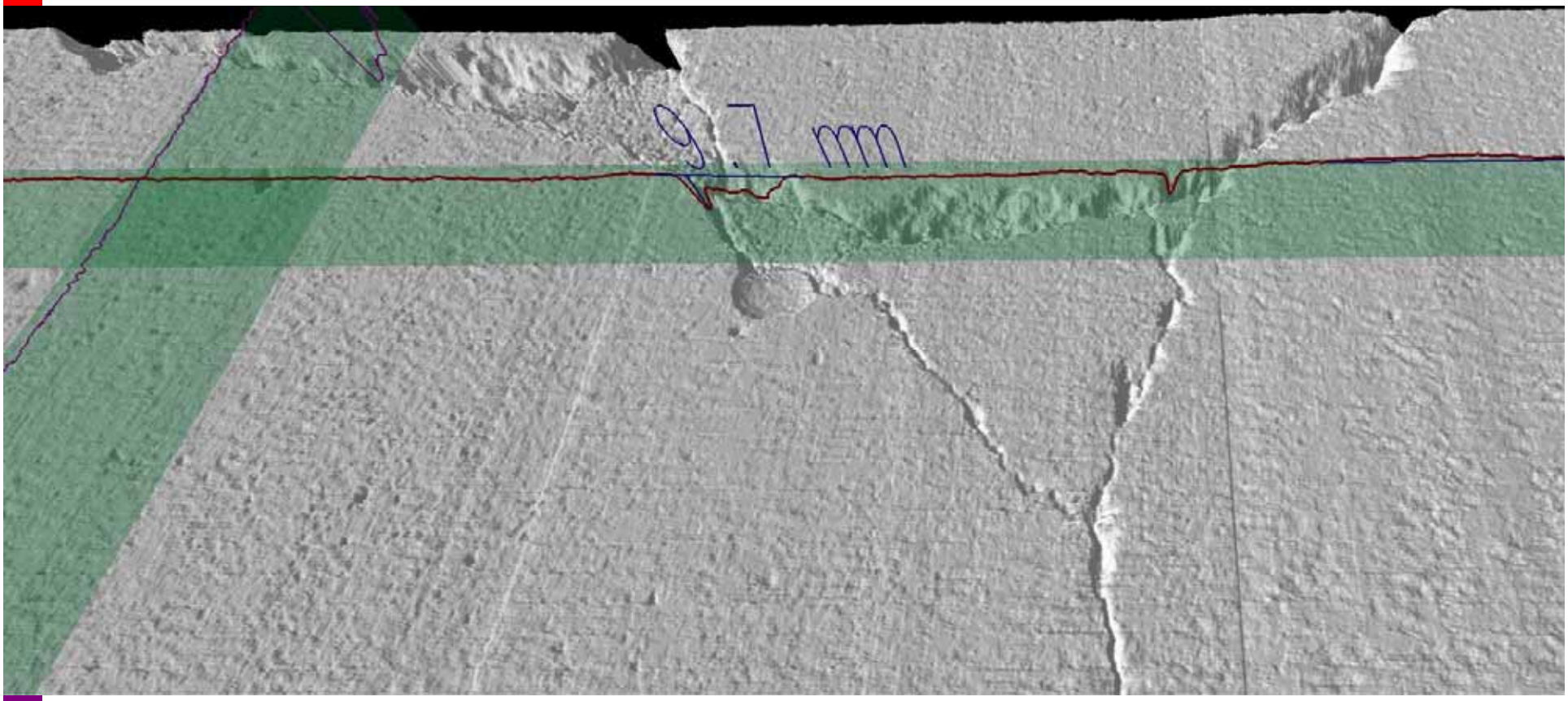

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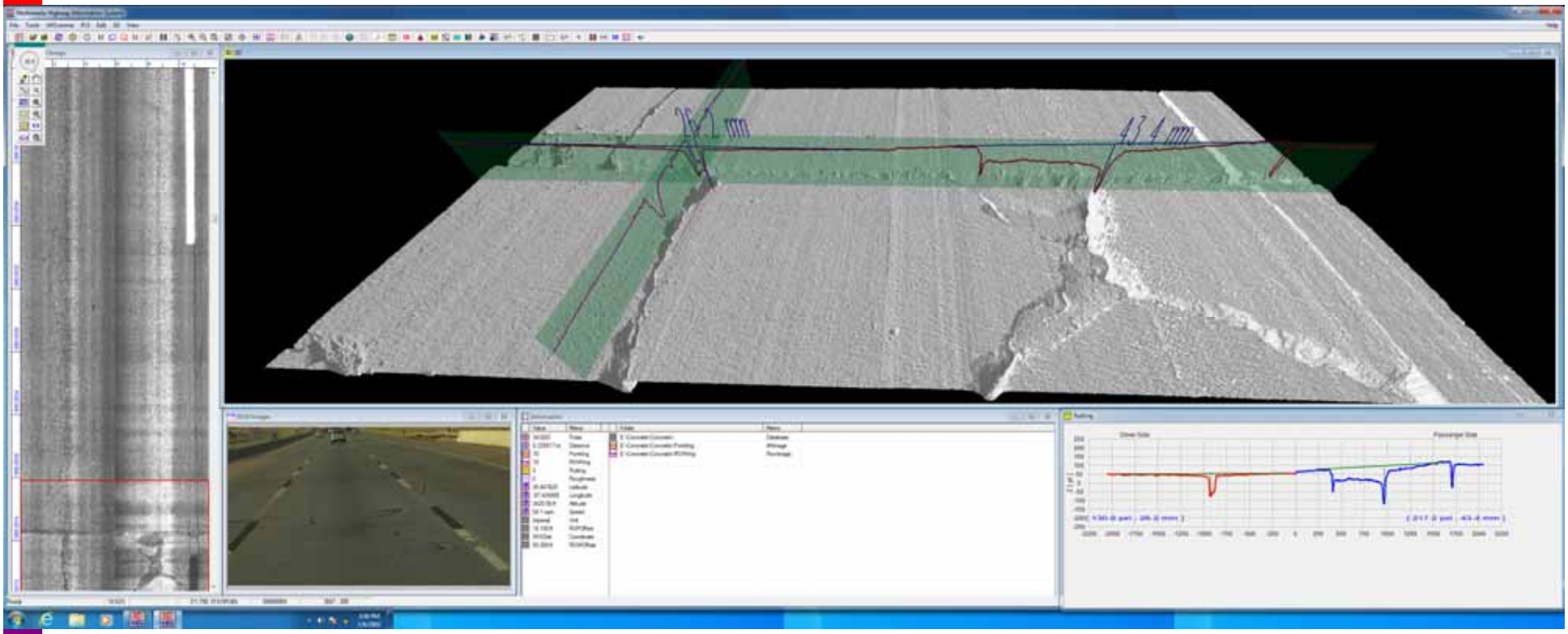

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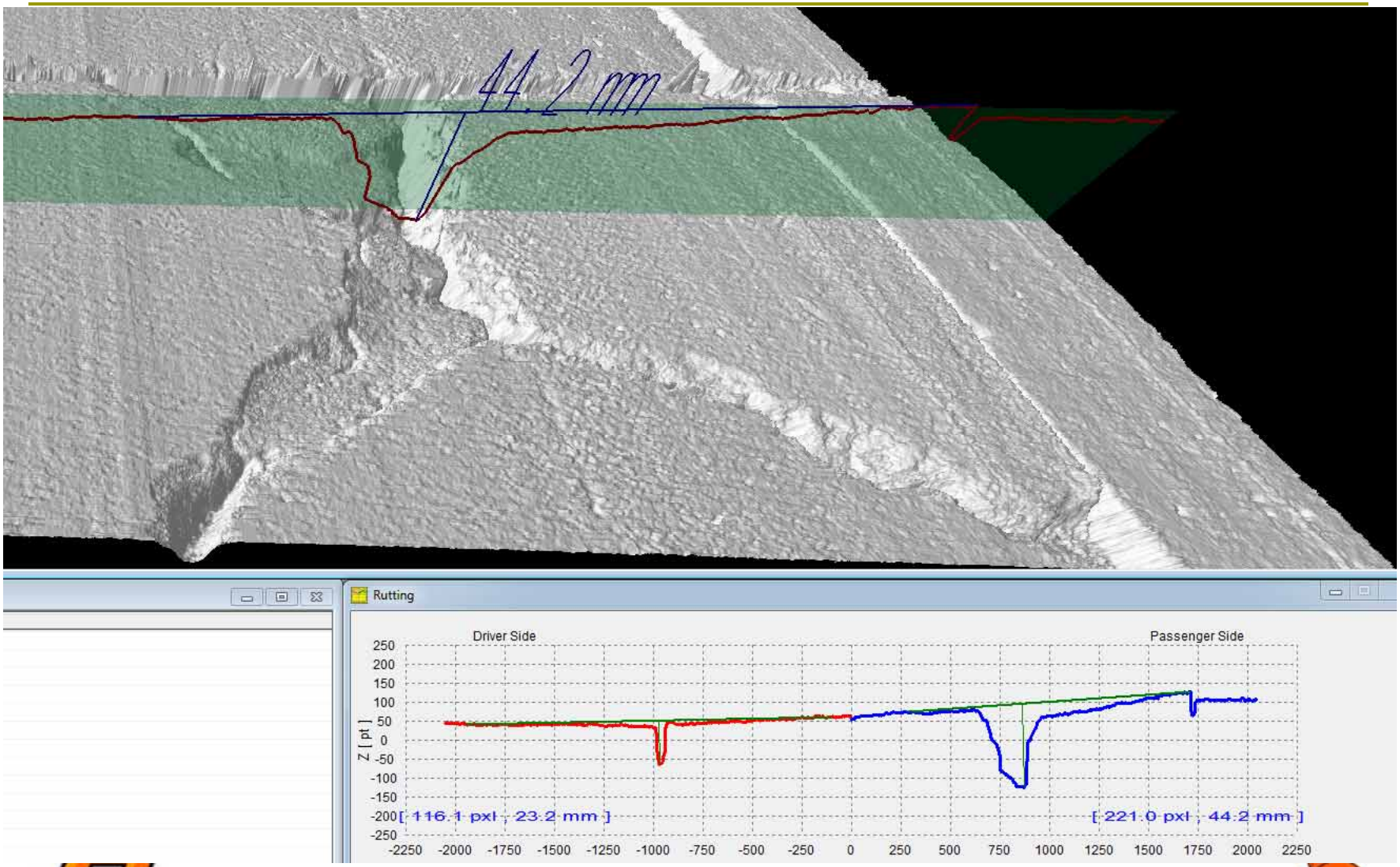

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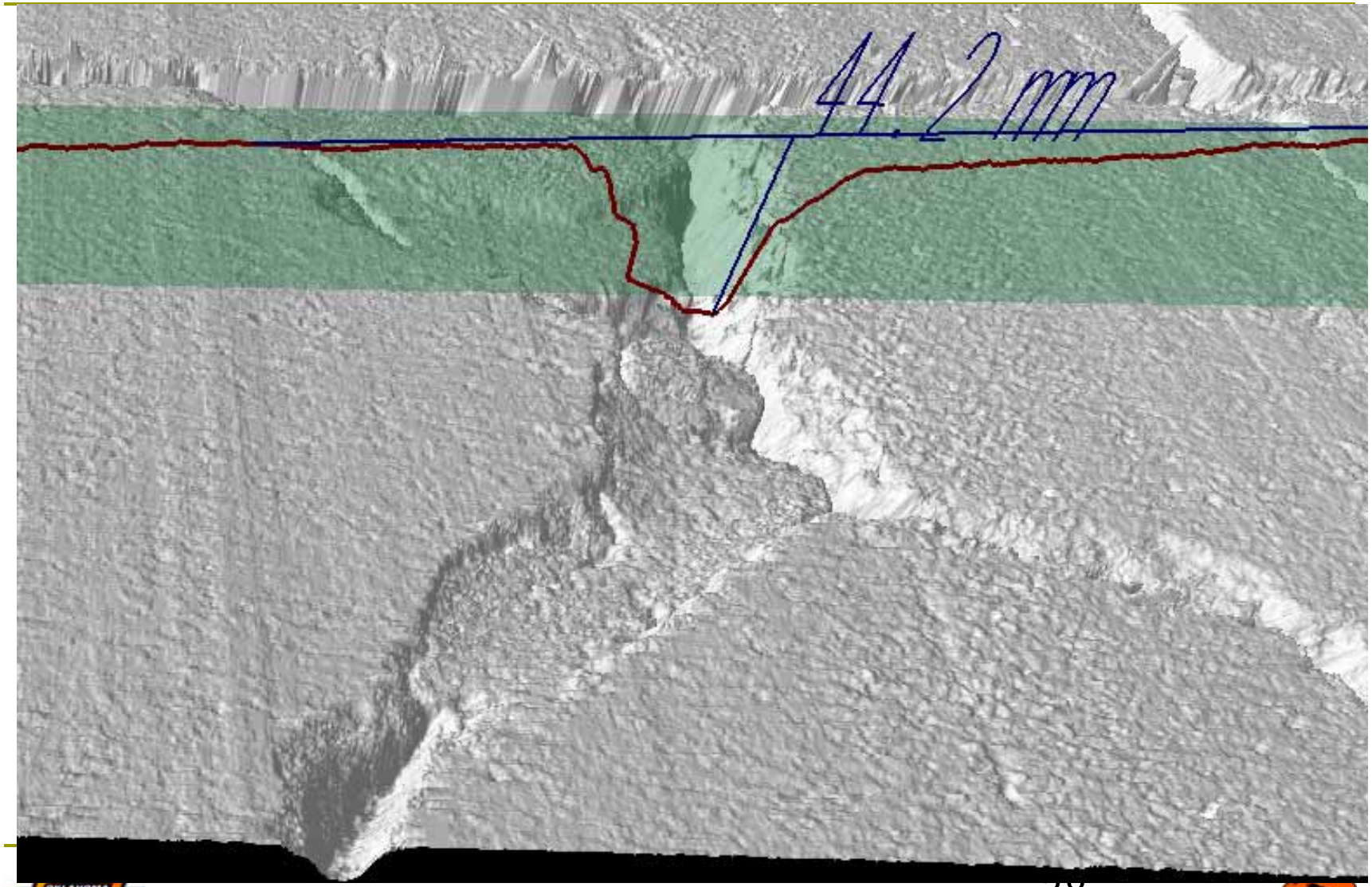

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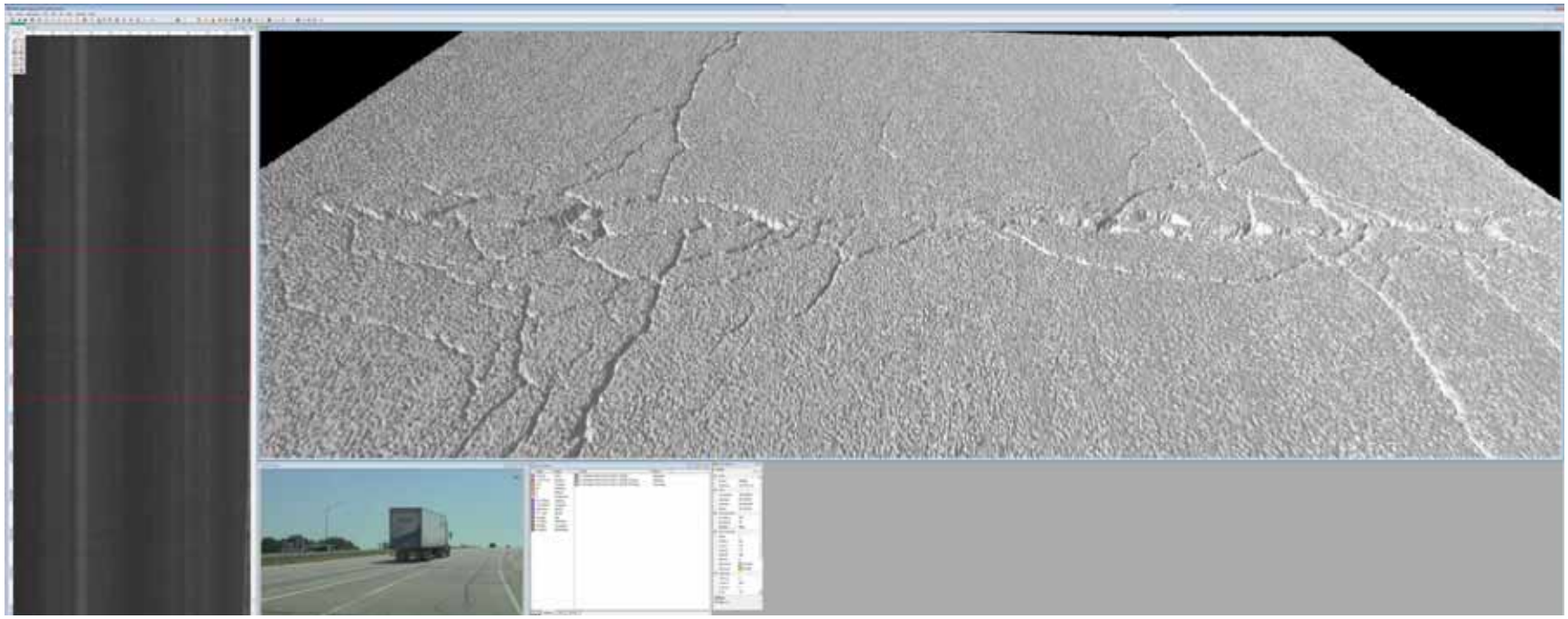

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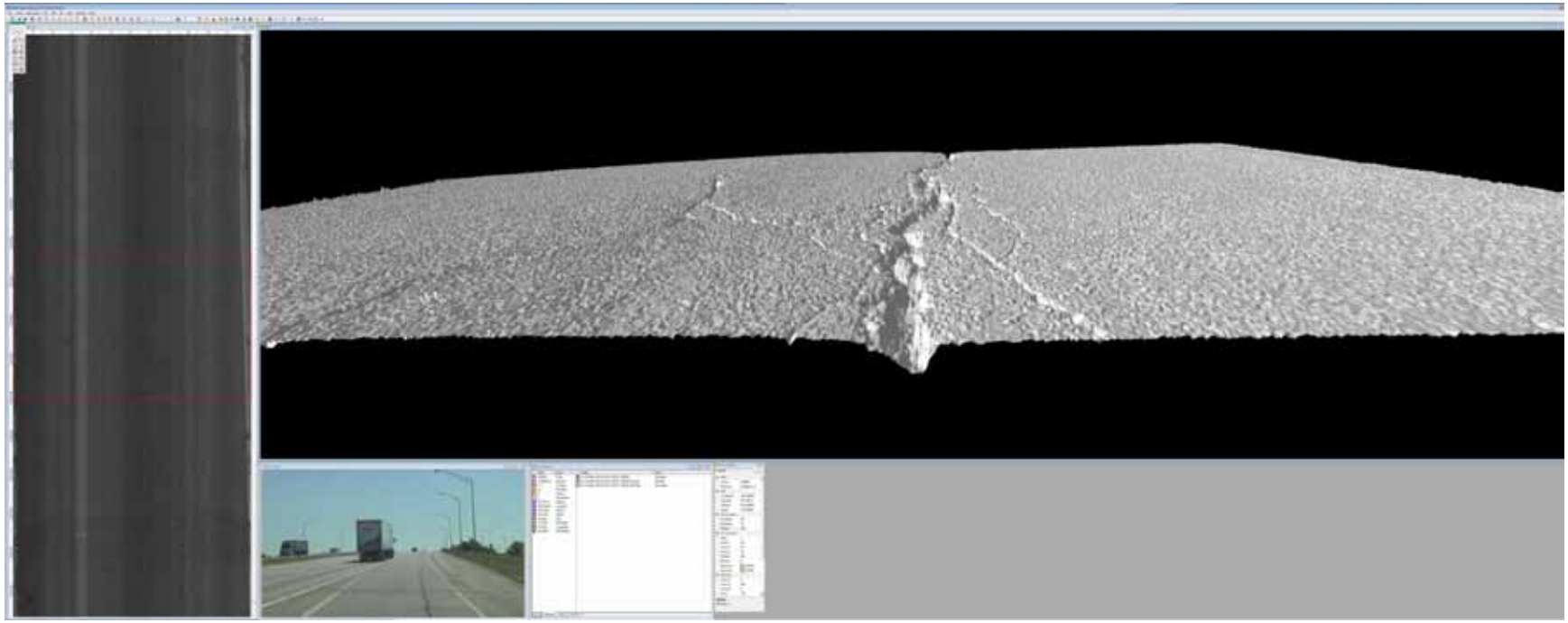

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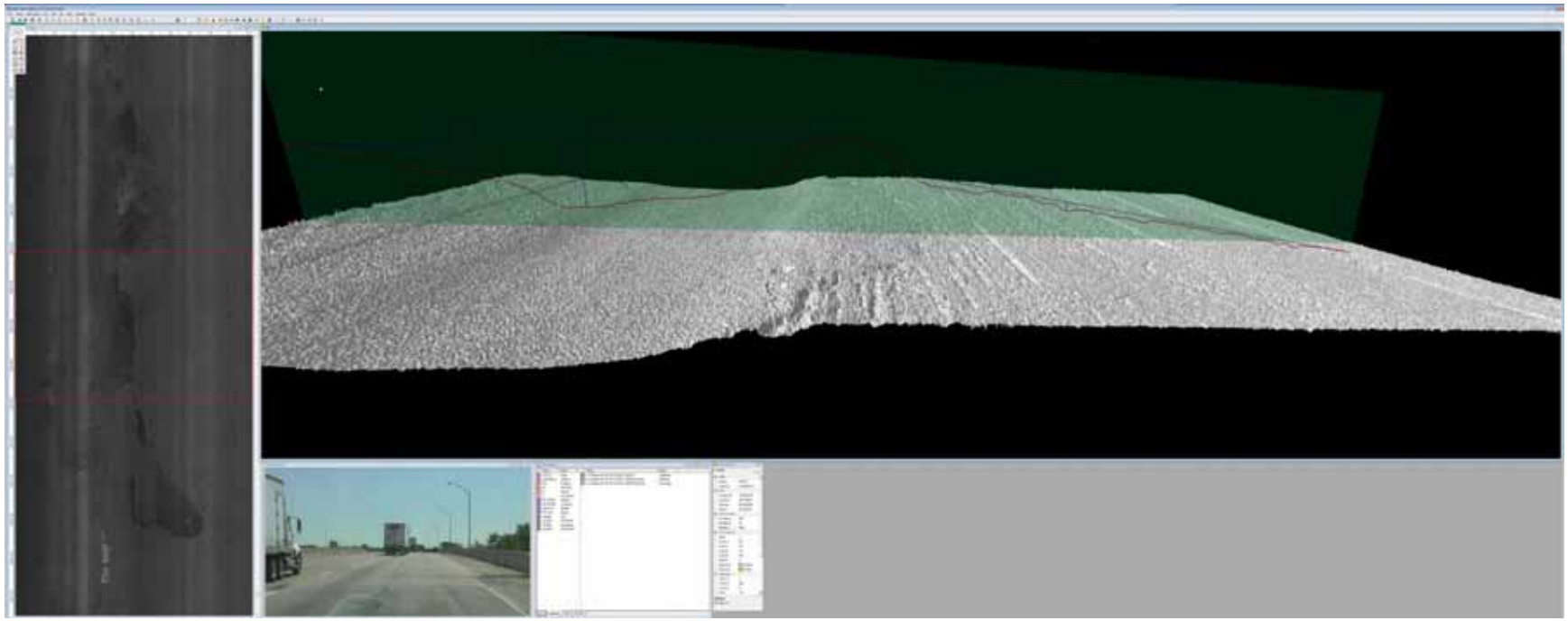

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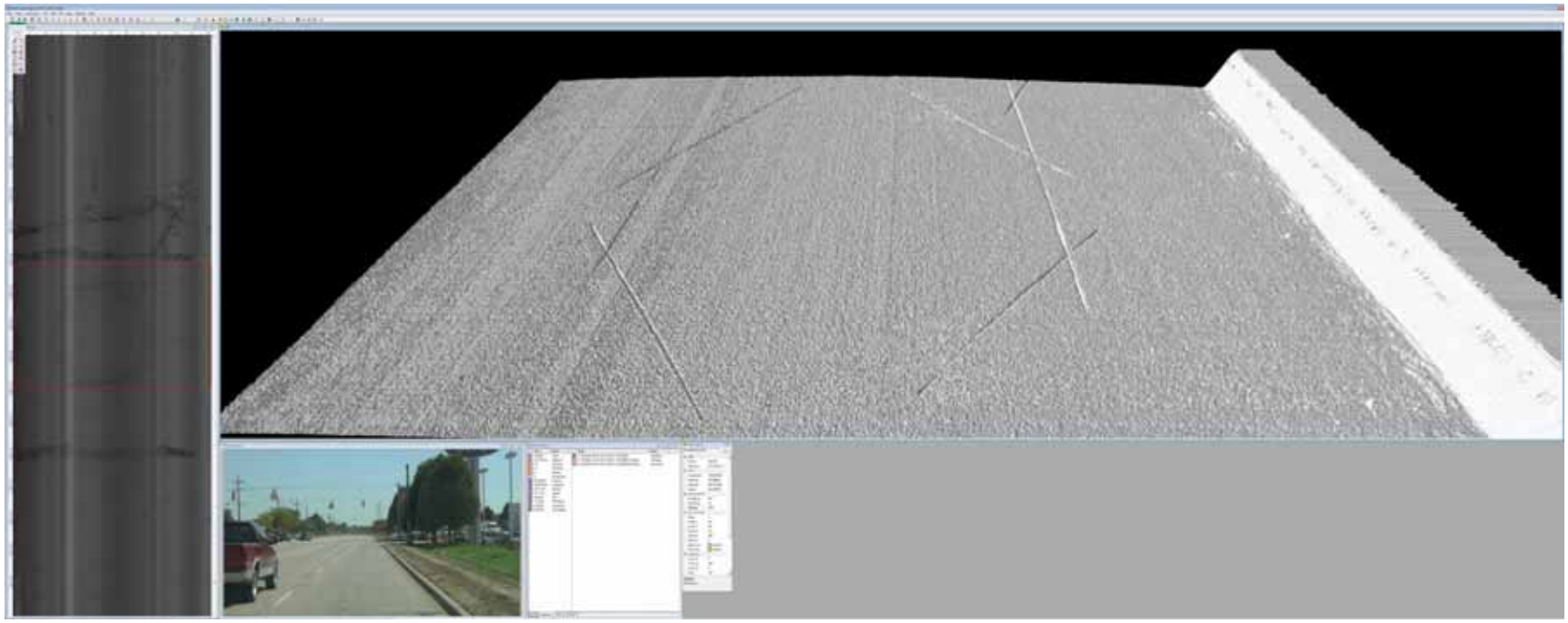

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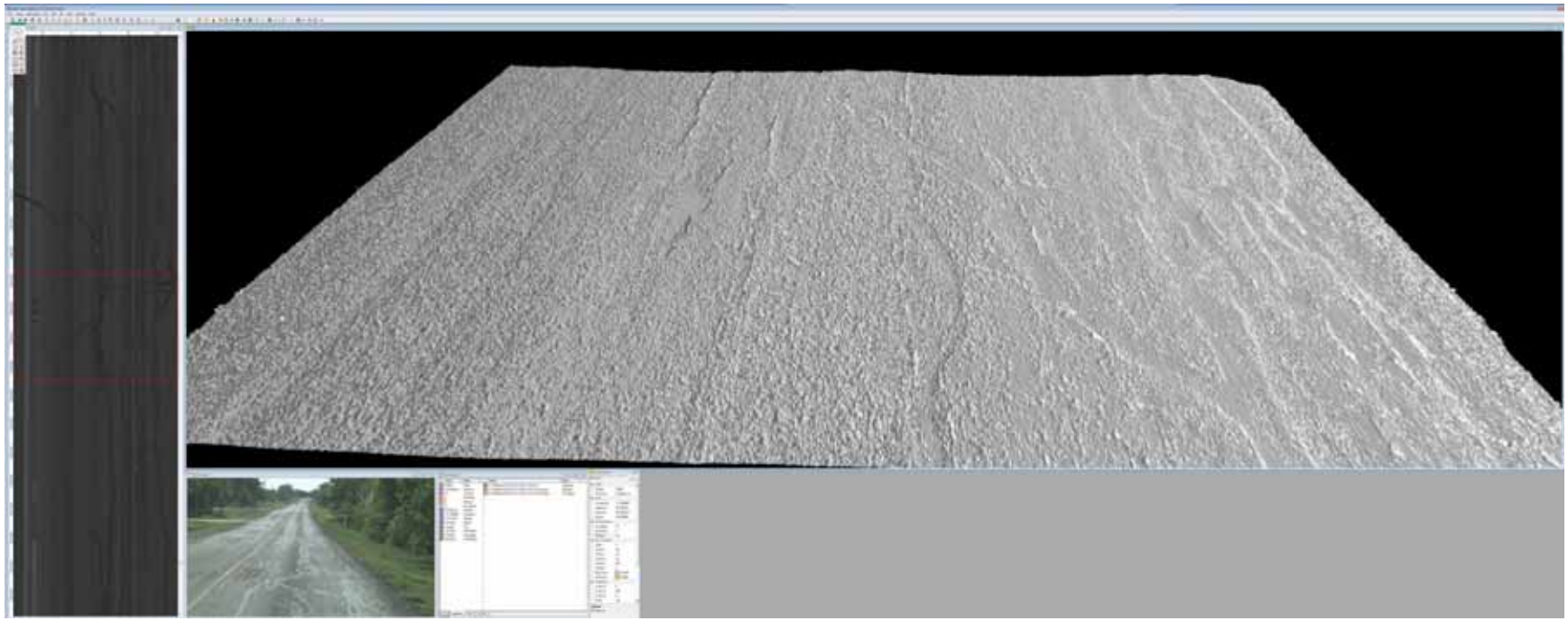

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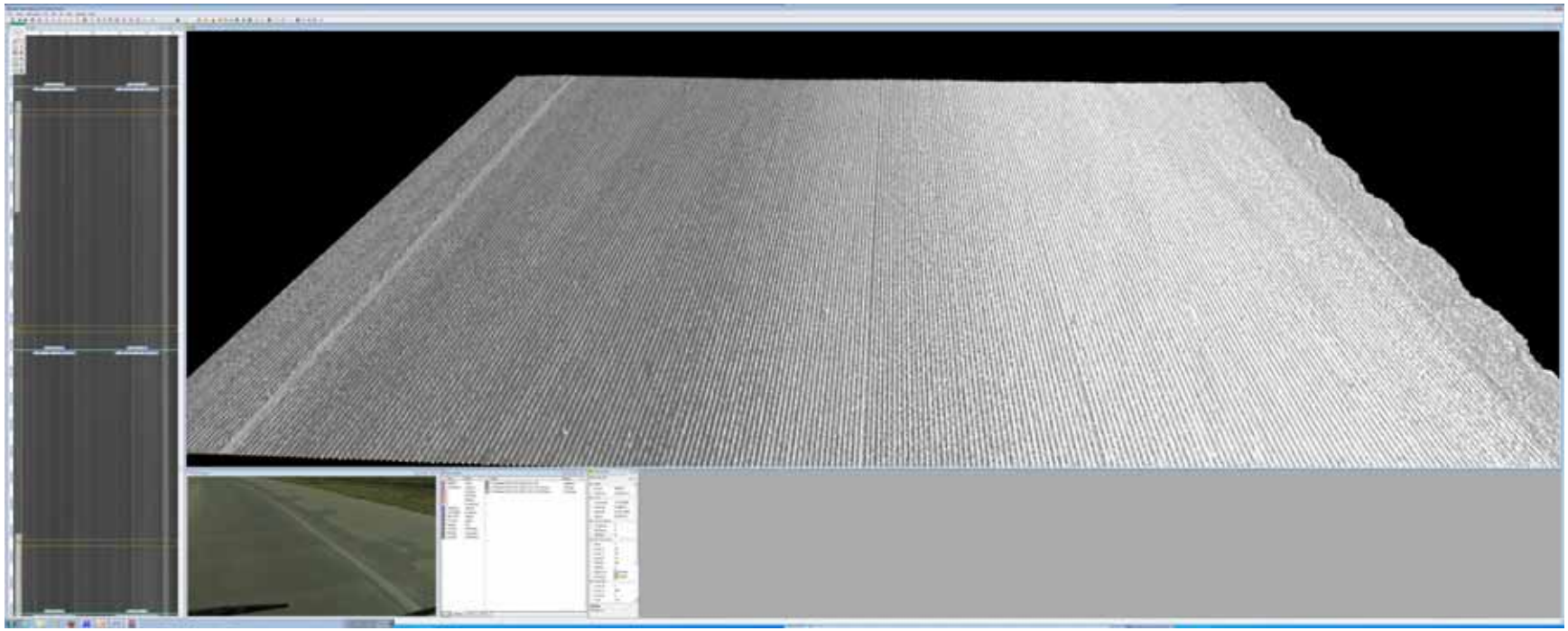

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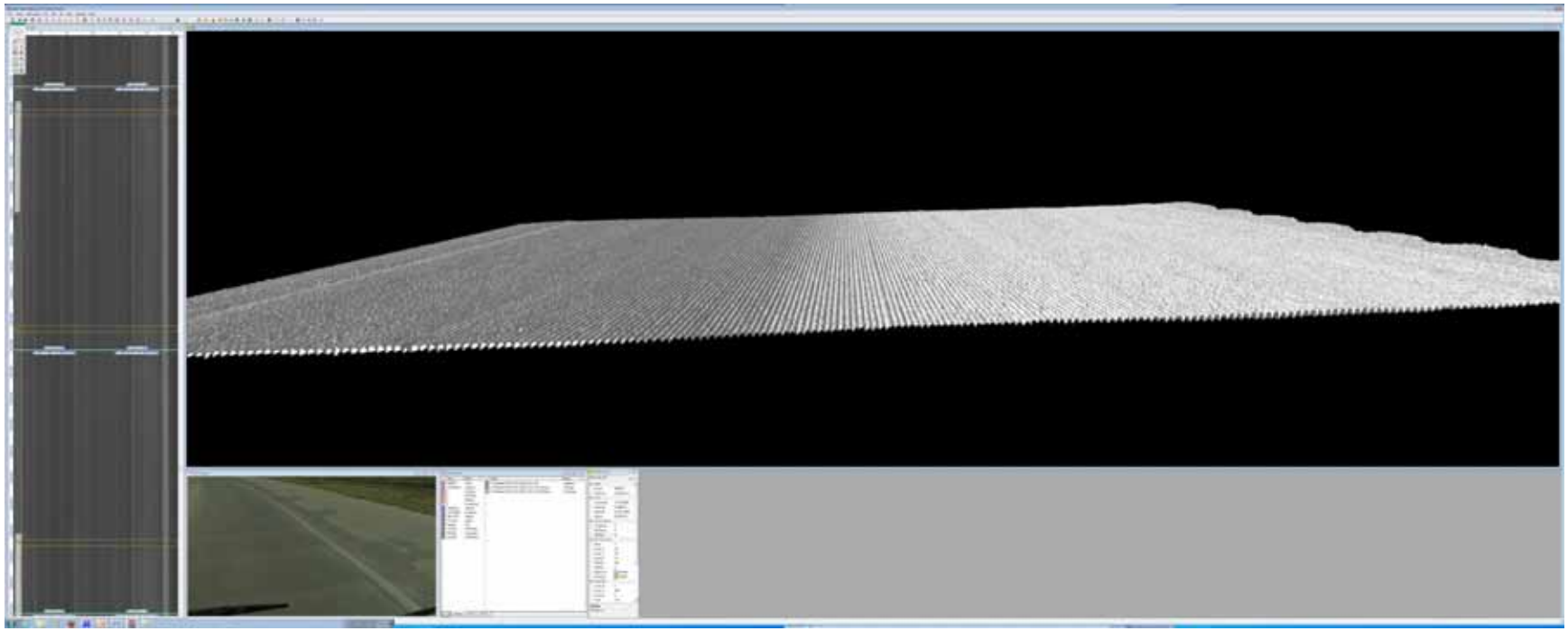

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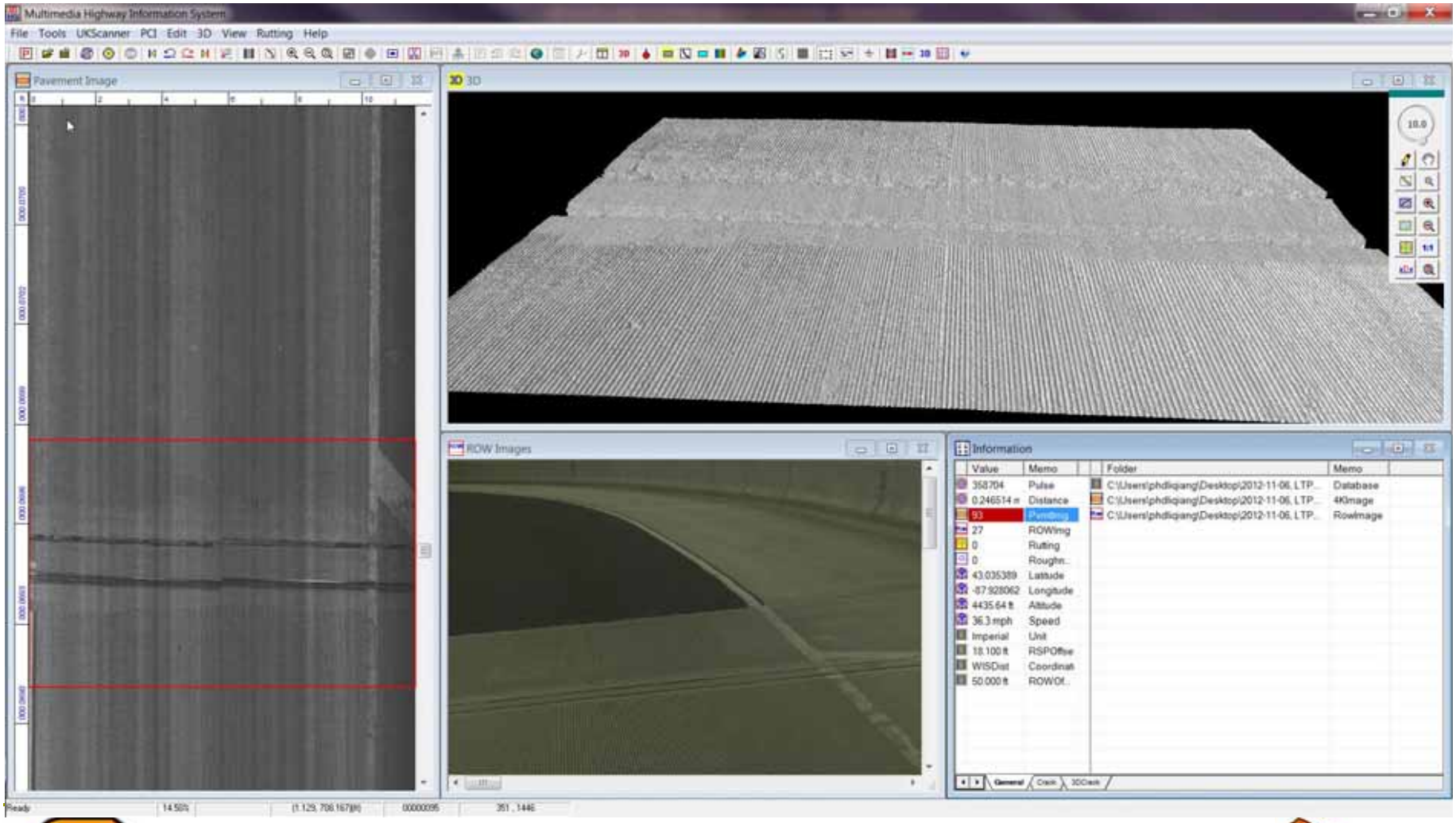

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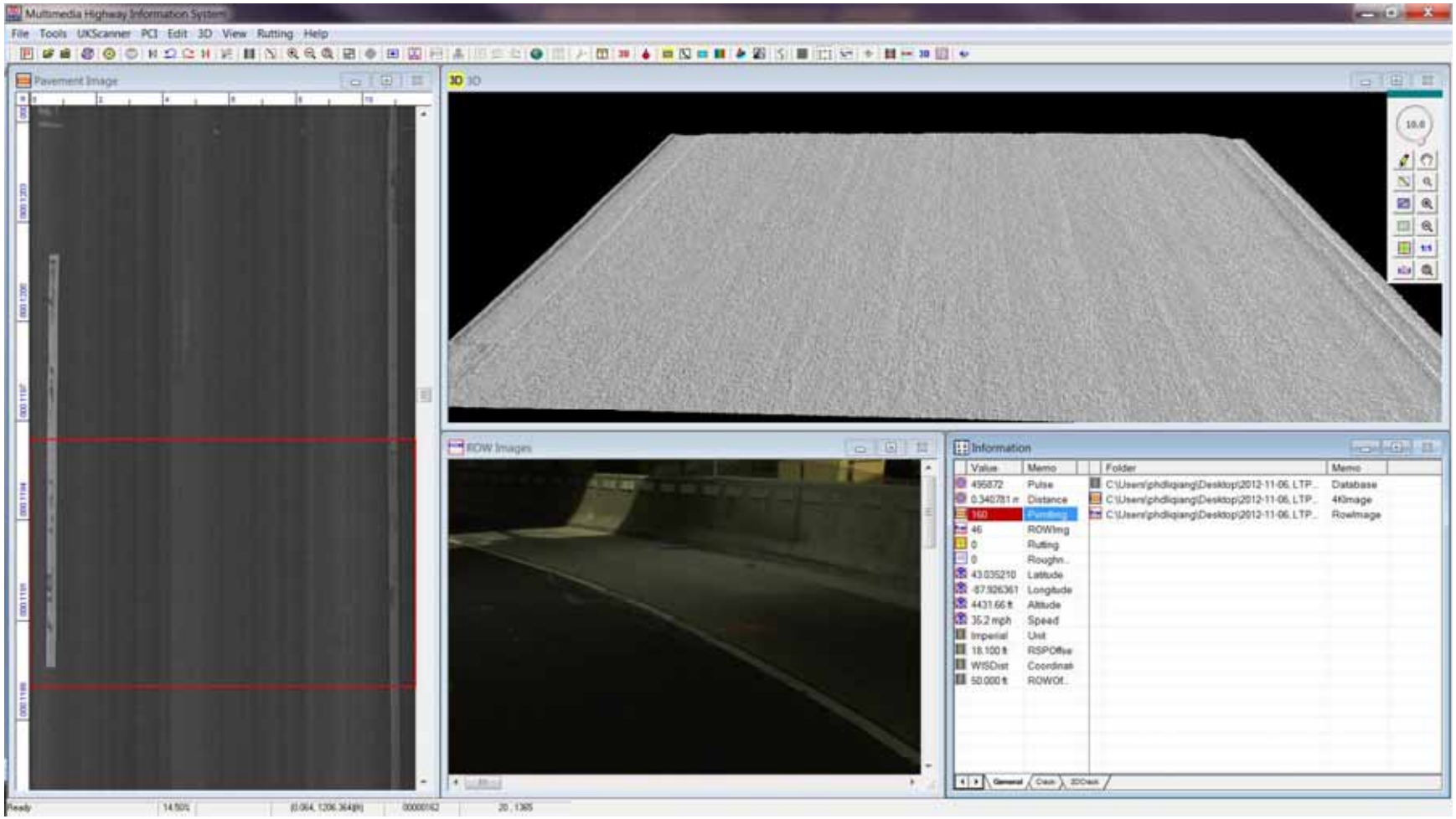
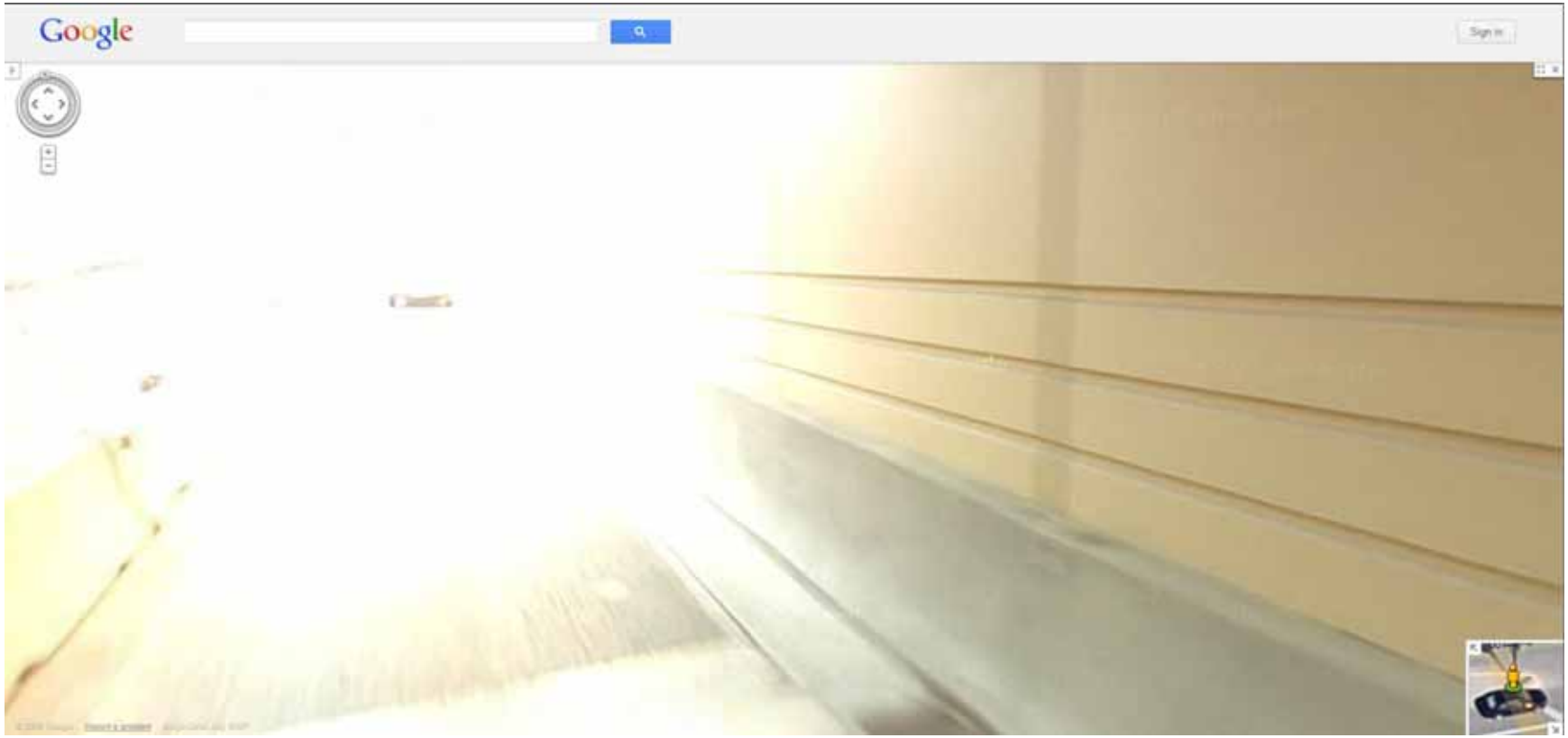
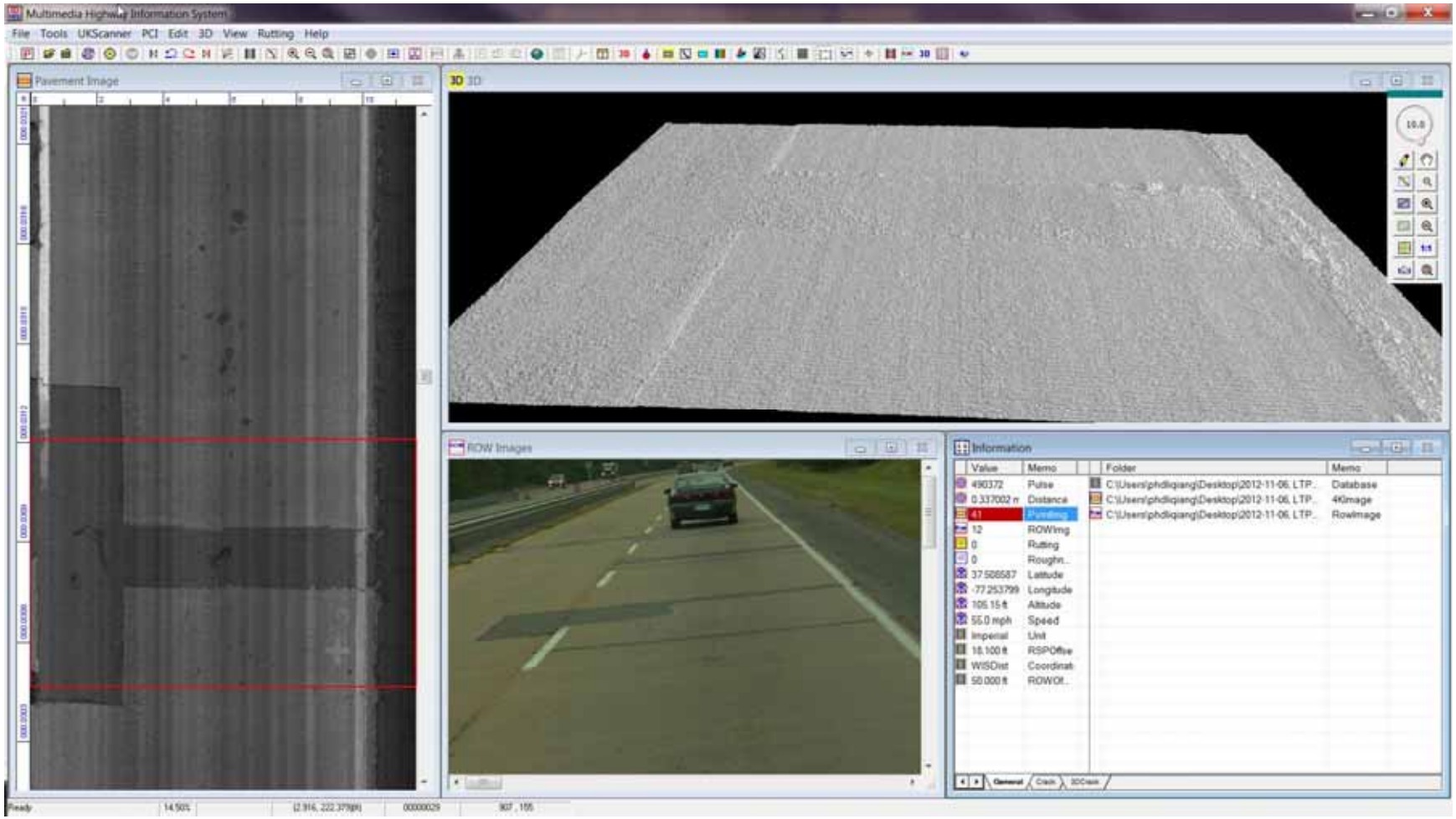


Google Image at the Same HFS



3D Data at 60MPH (100KM/h)



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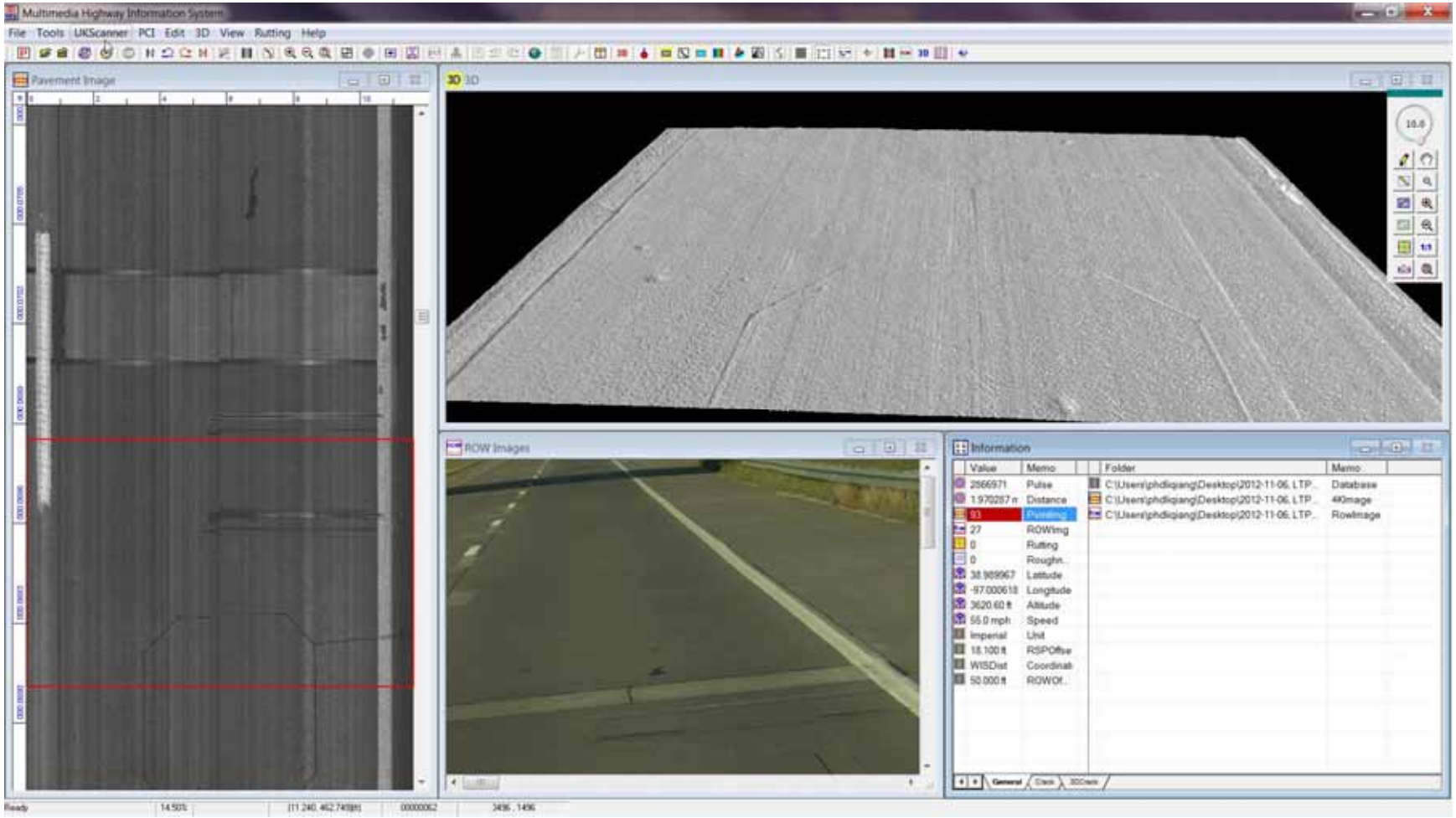

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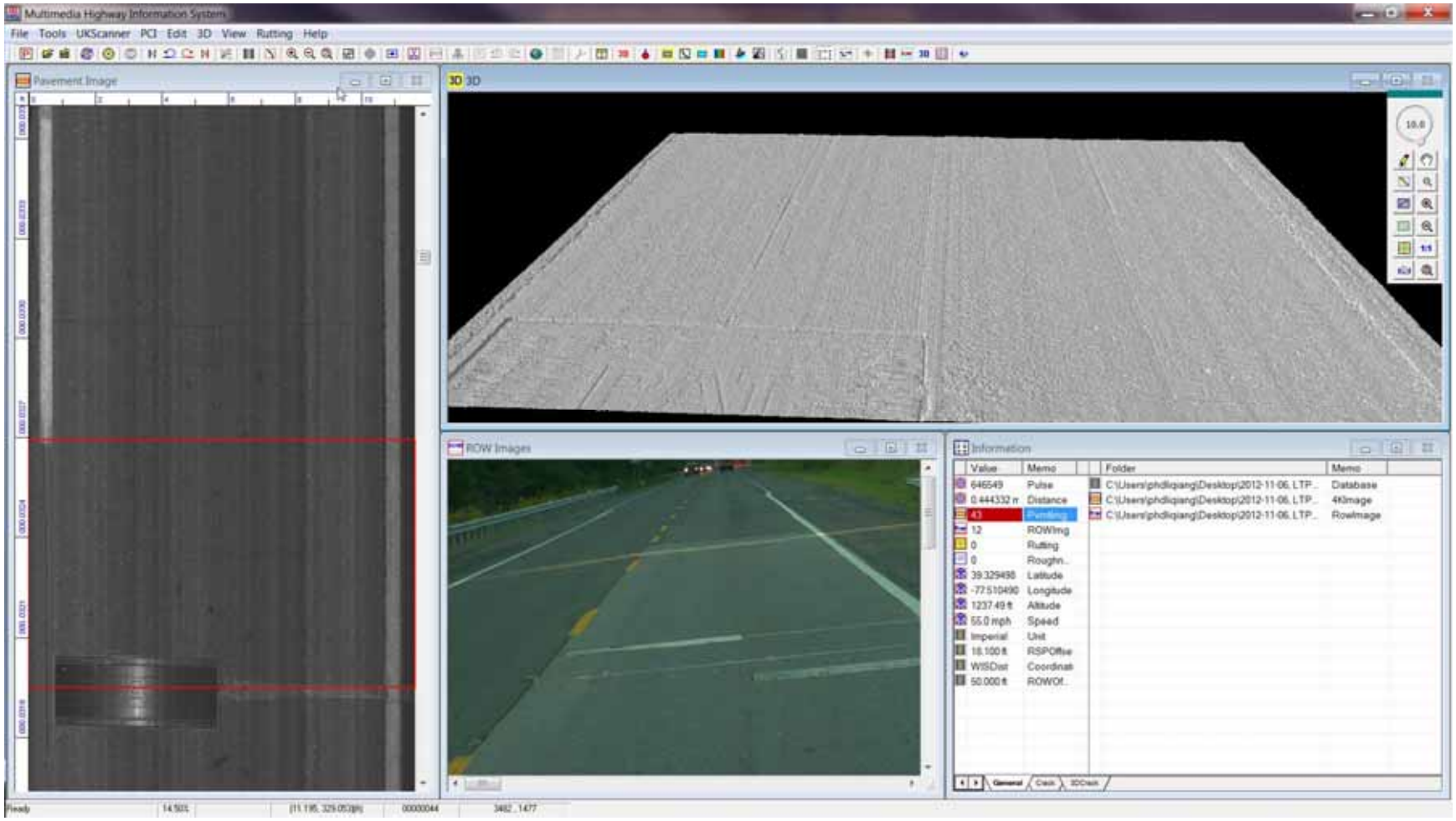
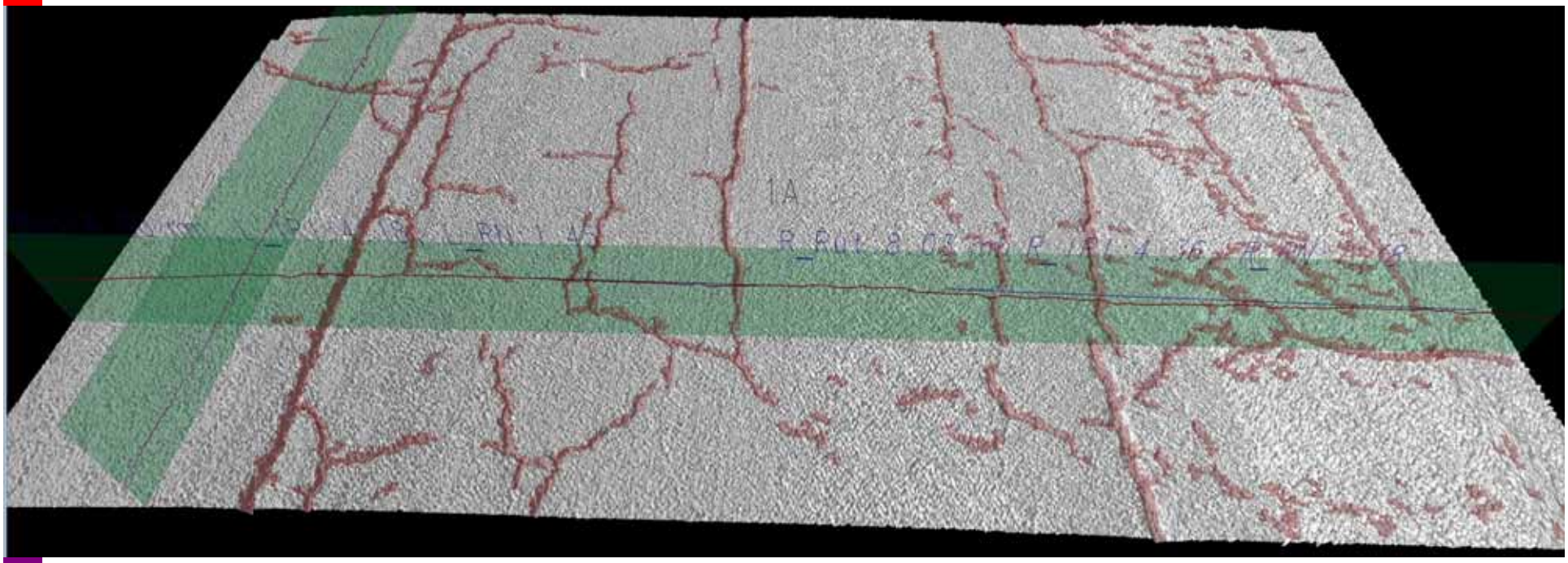


Information

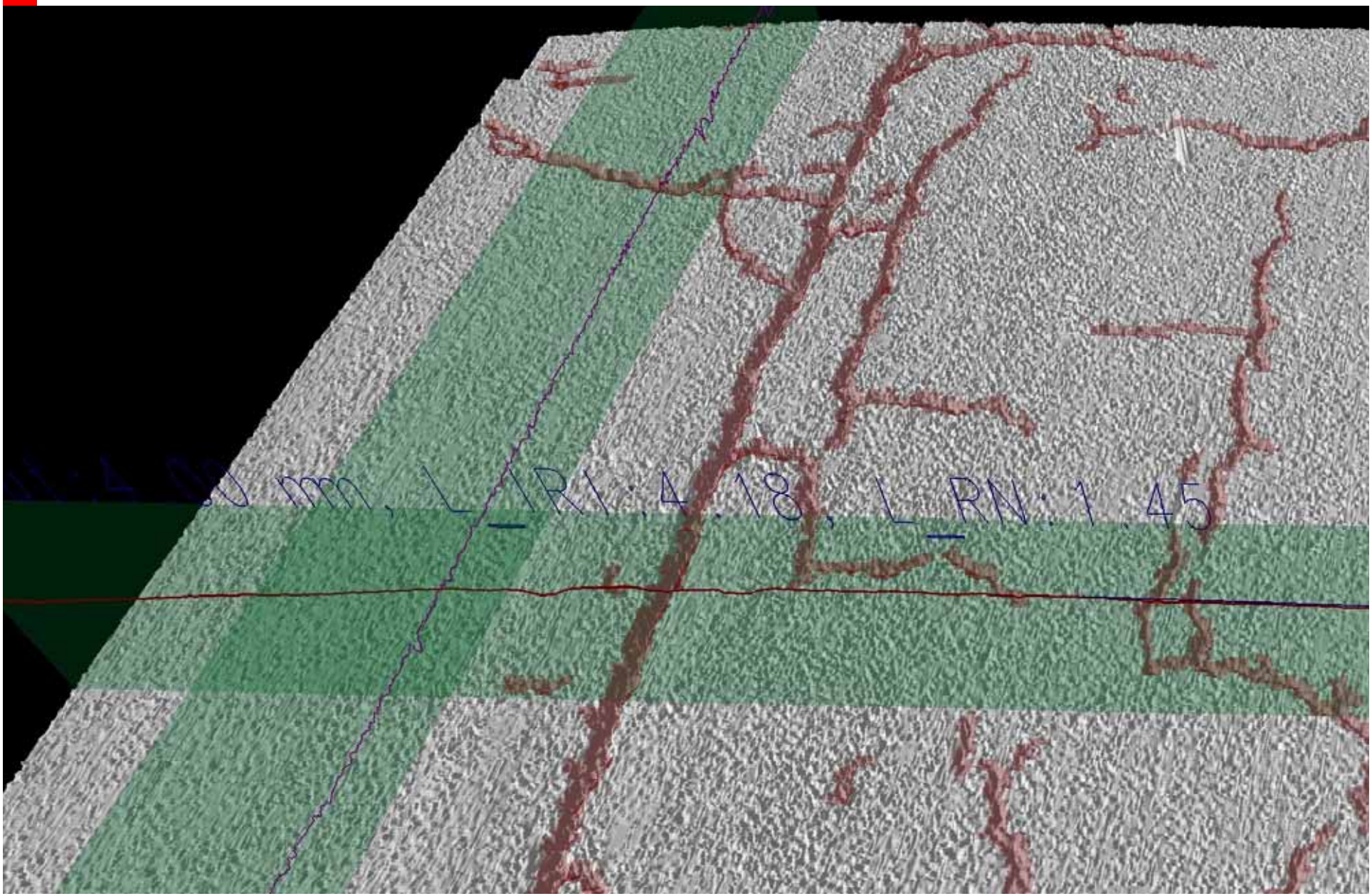
Value	Memo
343283	Pulse
0.235917 mi	Distance
70	PvmtImg
19	ROWImg
0	Rutting
0	Roughness
35.647625	Latitude
-97.424889	Longitude
3420.56 ft	Altitude
59.1 mph	Speed
Imperial	Unit
18.100 ft	RSPOffset
WISDist	Coordinate
50.000 ft	ROWOffset

60MPH

Cracking & Profiling



Zoomed-In, Cracking & Profiling



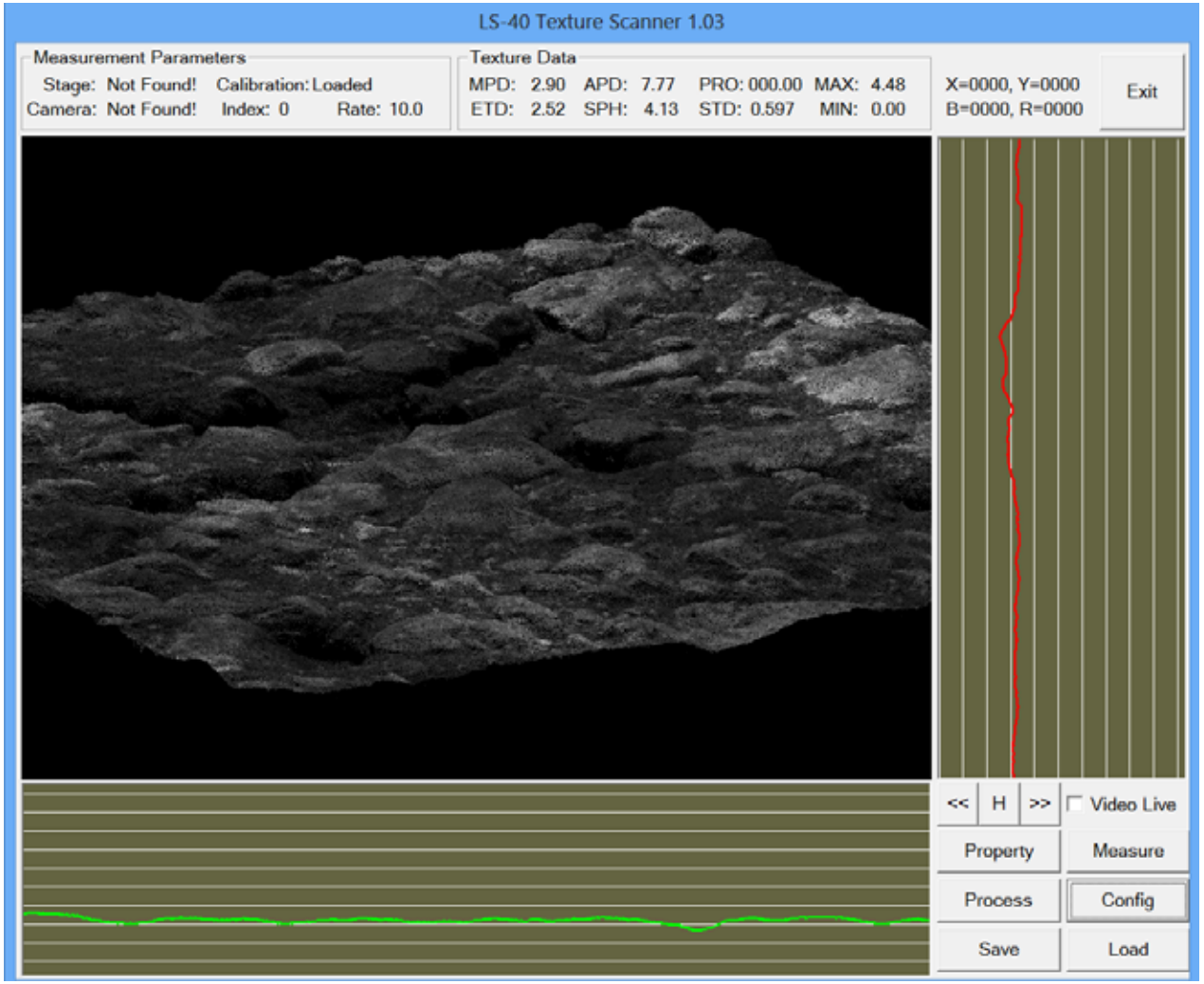
Evaluation of PaveVision3D Ultra

- Comparisons of Pavement Surface Texture Measurements with LS-40 Surface Analyzer
- Surface Drainage Evaluation Using IMU and 1mm 3D Texture Data
- Automated Groove Identification and Measurement
- Evaluation of Pavement Transverse Deformation Based on AASHTO PP69-10

LS-40 Pavement Surface Analyzer

- Scanned Area:
  - 4.5'' long by 4'' wide
- Data Pixel Quantity
  - 2048 x2448
- Horizontal Resolution
  - 0.056mm

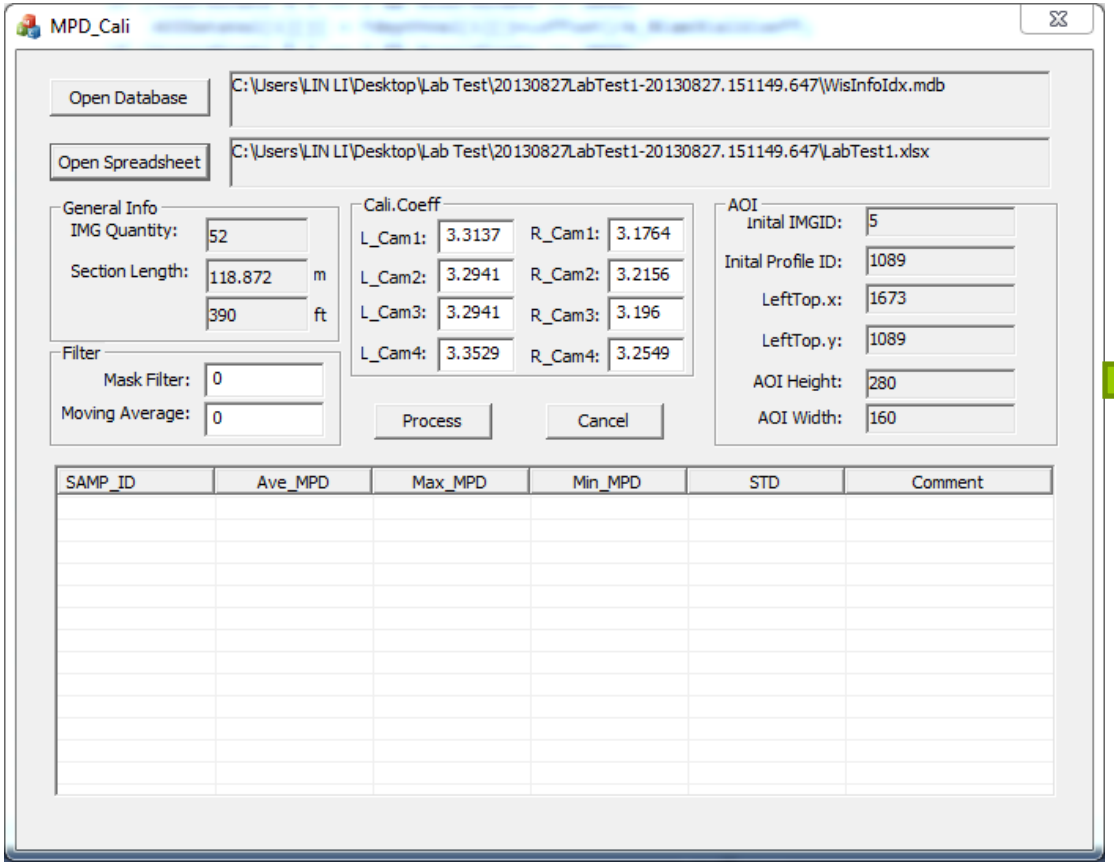
LS-40 Software Interface

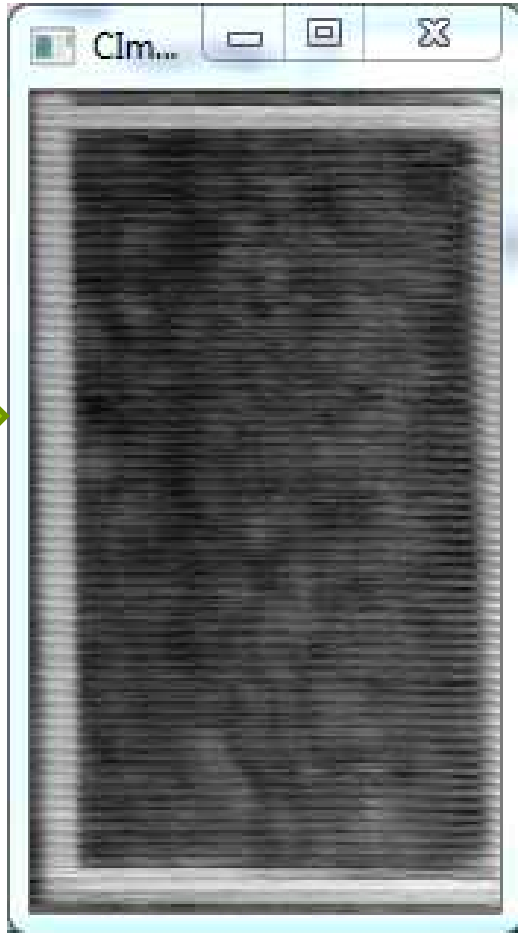


Experimental Setup

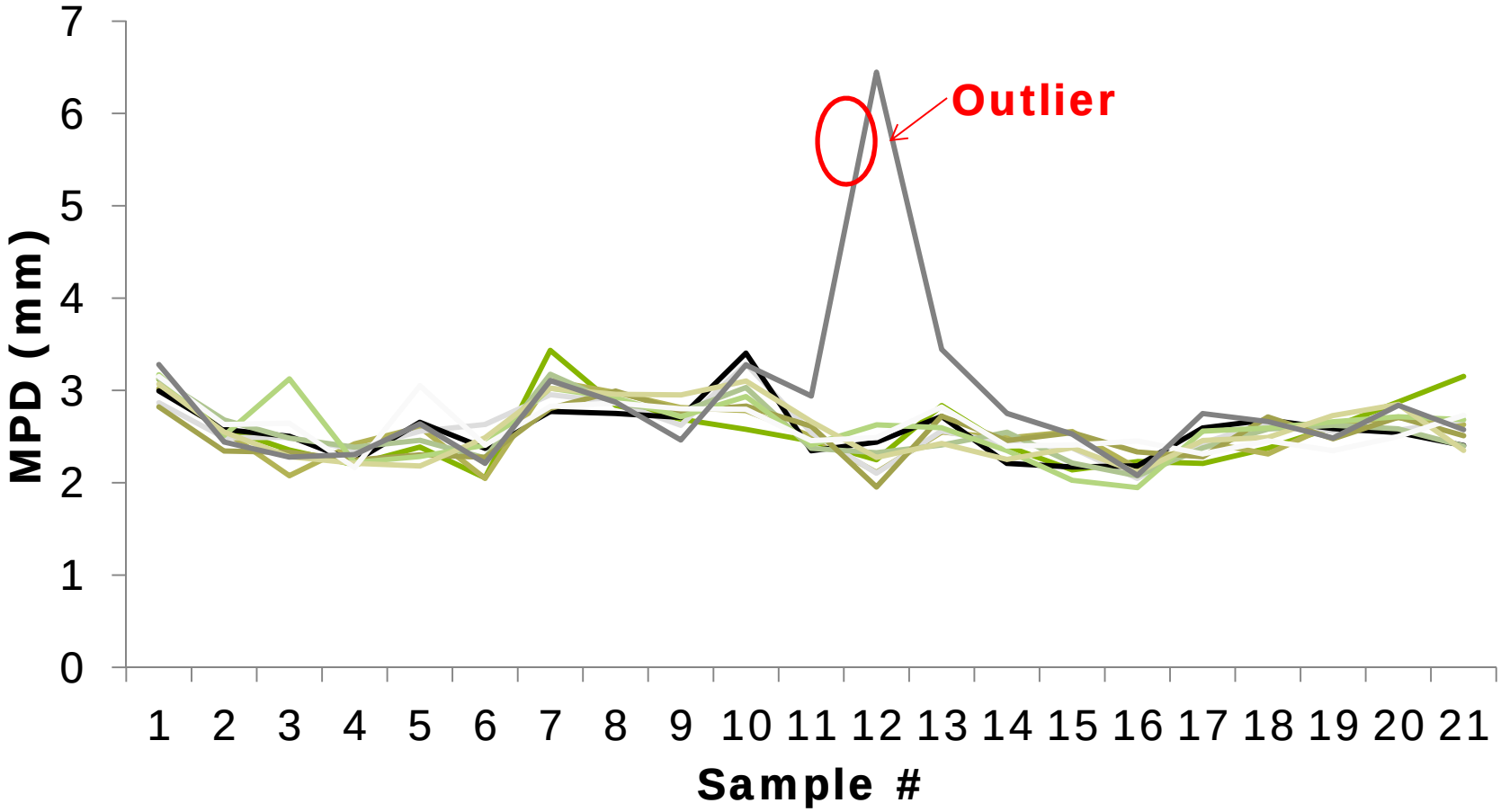
- 21 areas marked on pavement
  - Evenly spaced (15ft)
  - 1ft long by 6 in wide
- Texture Measurements
  - Within marked area
  - LS40 MPD: static 5 runs
  - PaveVision3D MPD: two speeds, 10 runs each

PaveVision3D Texture Analysis

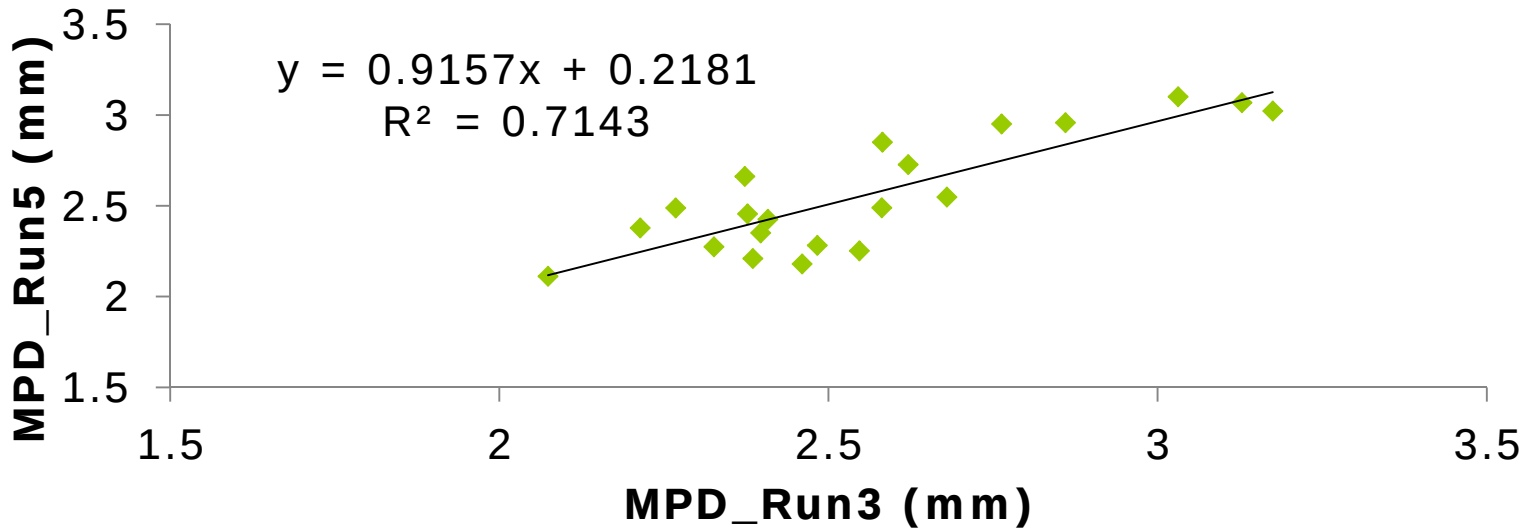




PaveVision3D MPD (7mph)

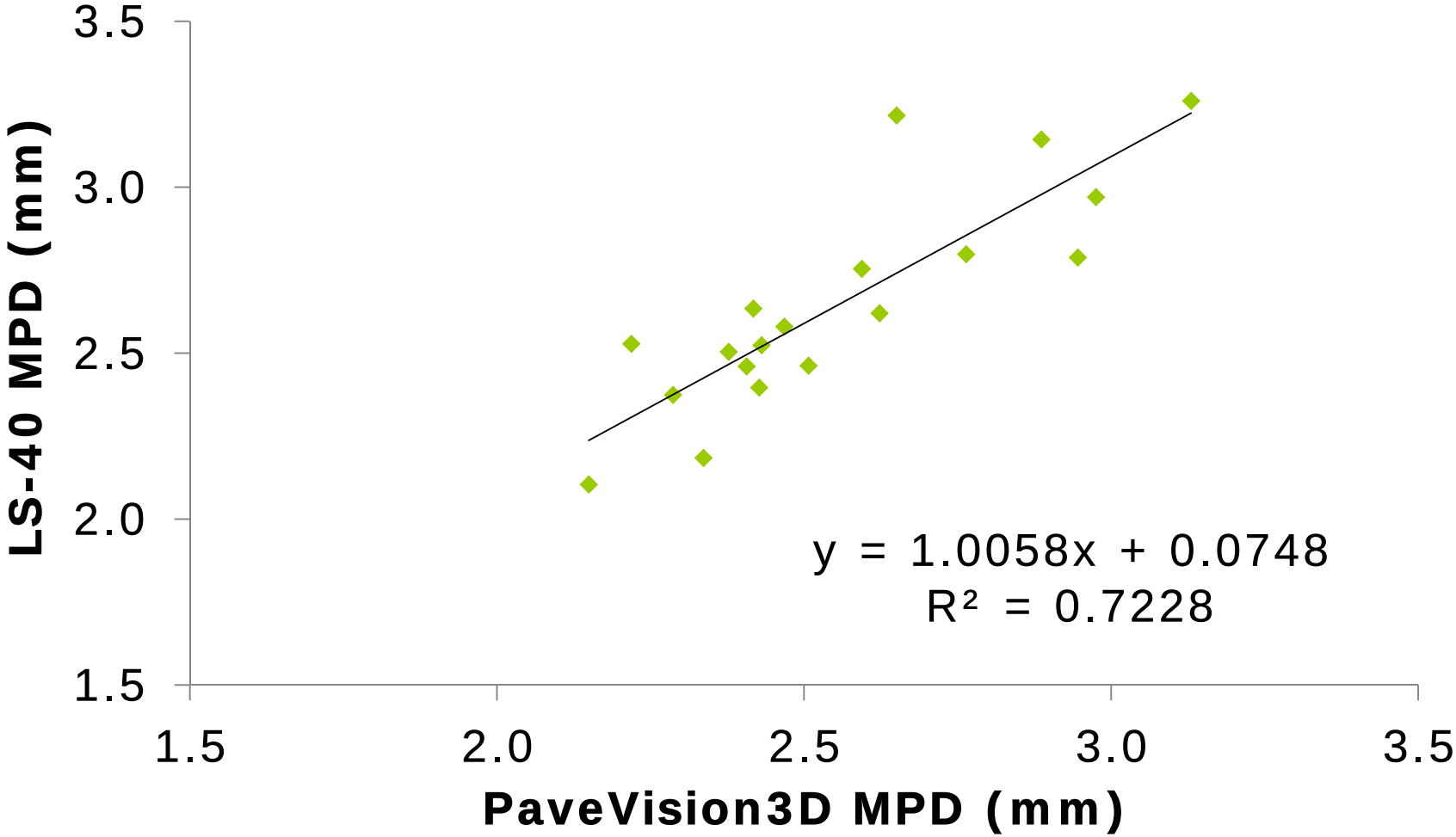


Correlation Analysis(7mph)

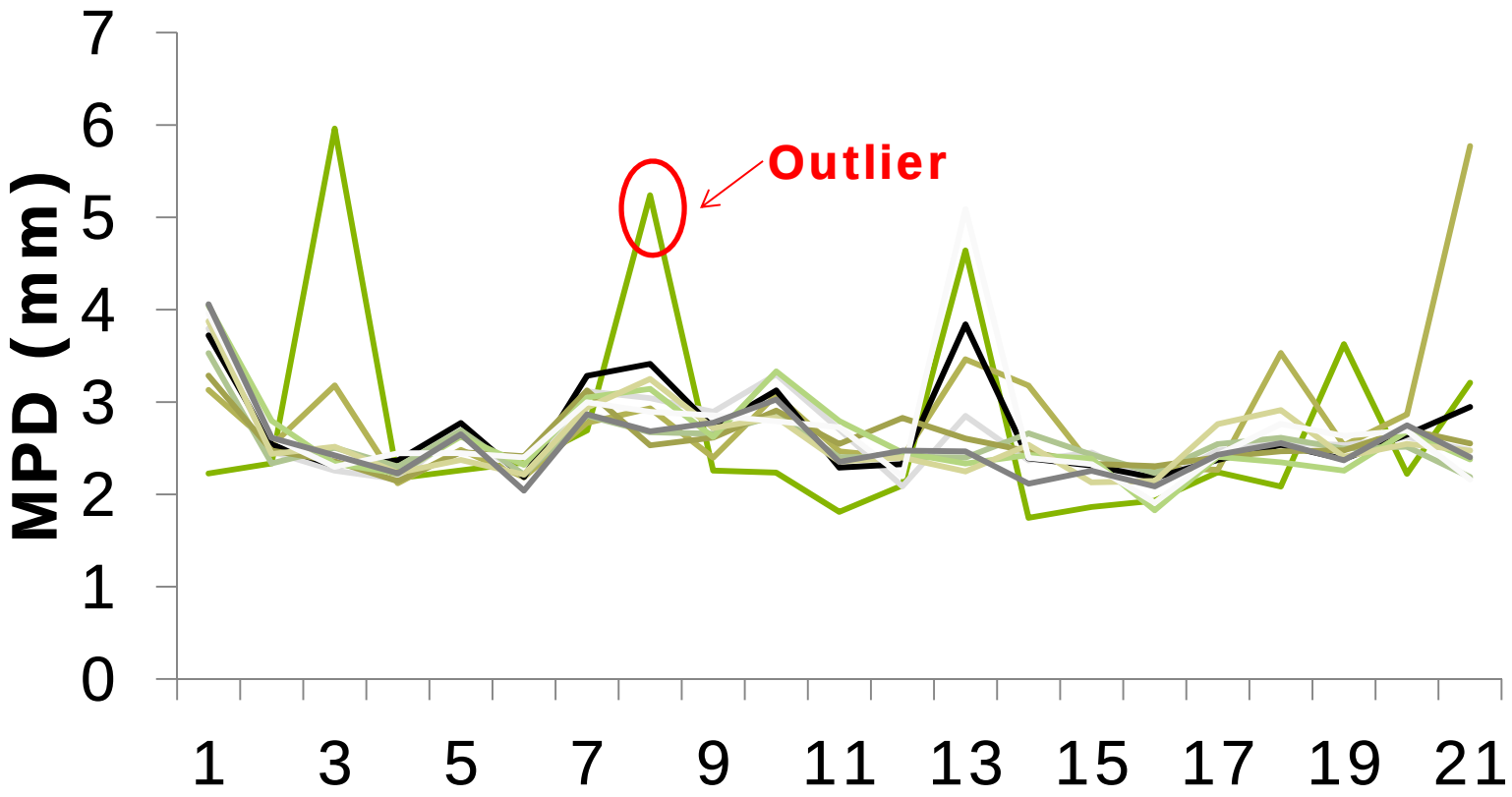


	run 1	run 2	run 3	run4	run5
run 1	1				
run 2	0.68	1			
run 3	0.66	0.63	1		
run 4	0.56	0.34	0.46	1	
run 5	0.63	0.55	0.71	0.61	1

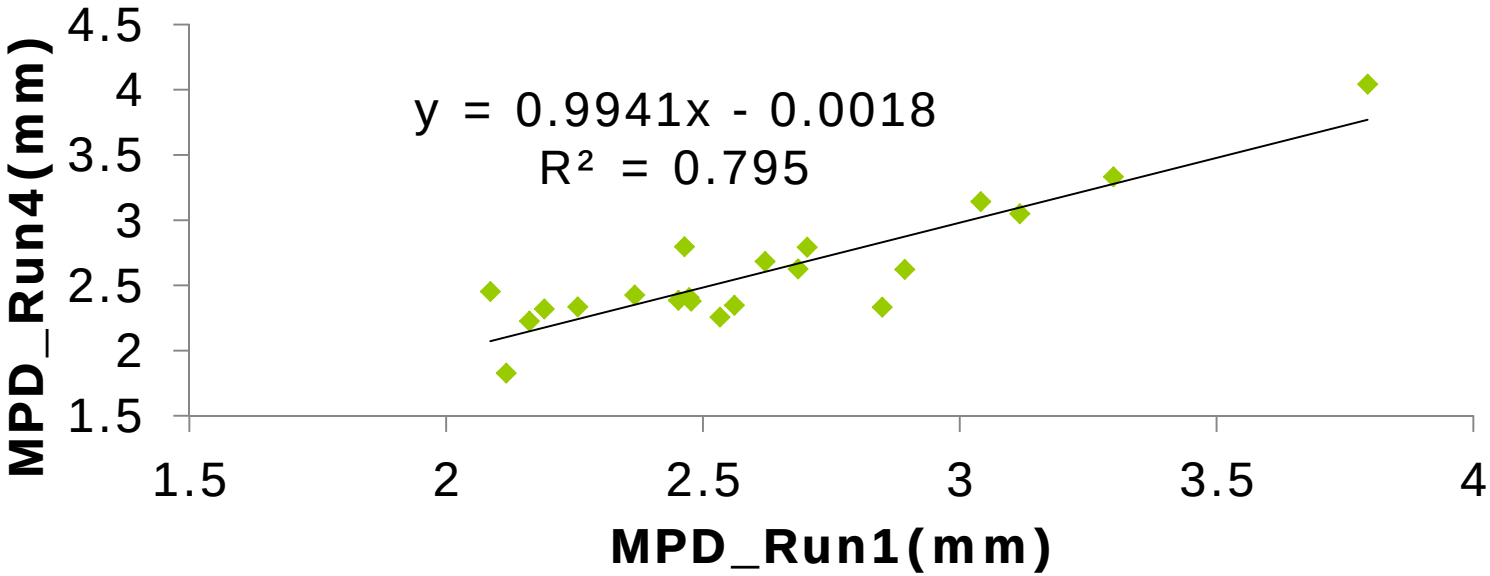
Comparison Analysis (7mph)



PaveVision3D MPD (15mph)

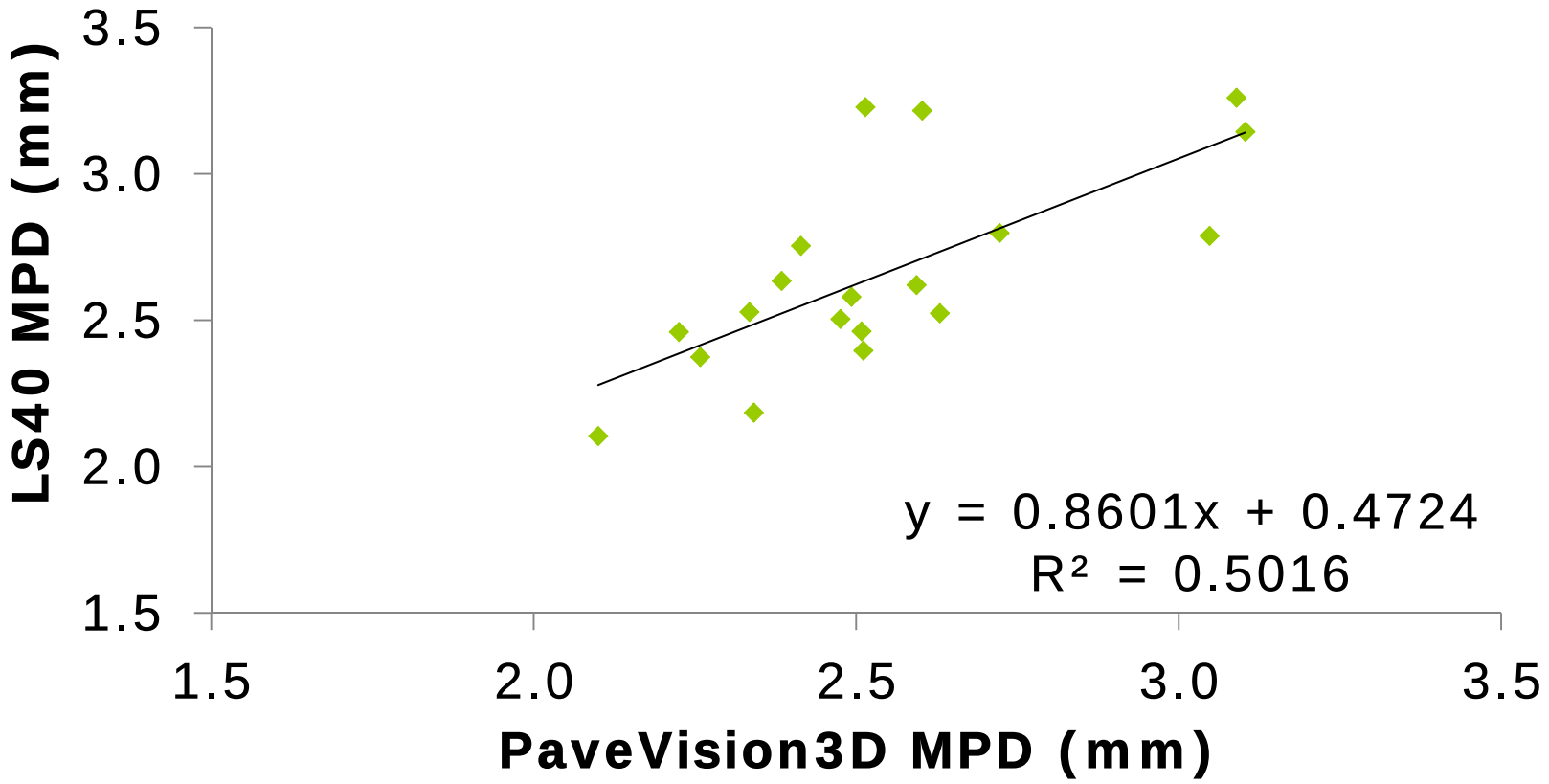


Correlation Analysis (15mph)



	run 1	run 2	run 3	run 4	run 5
run 1	1				
run 2	0.67	1			
run 3	0.72	0.35	1		
run 4	0.80	0.43	0.71	1	
run 5	0.64	0.38	0.76	0.69	1

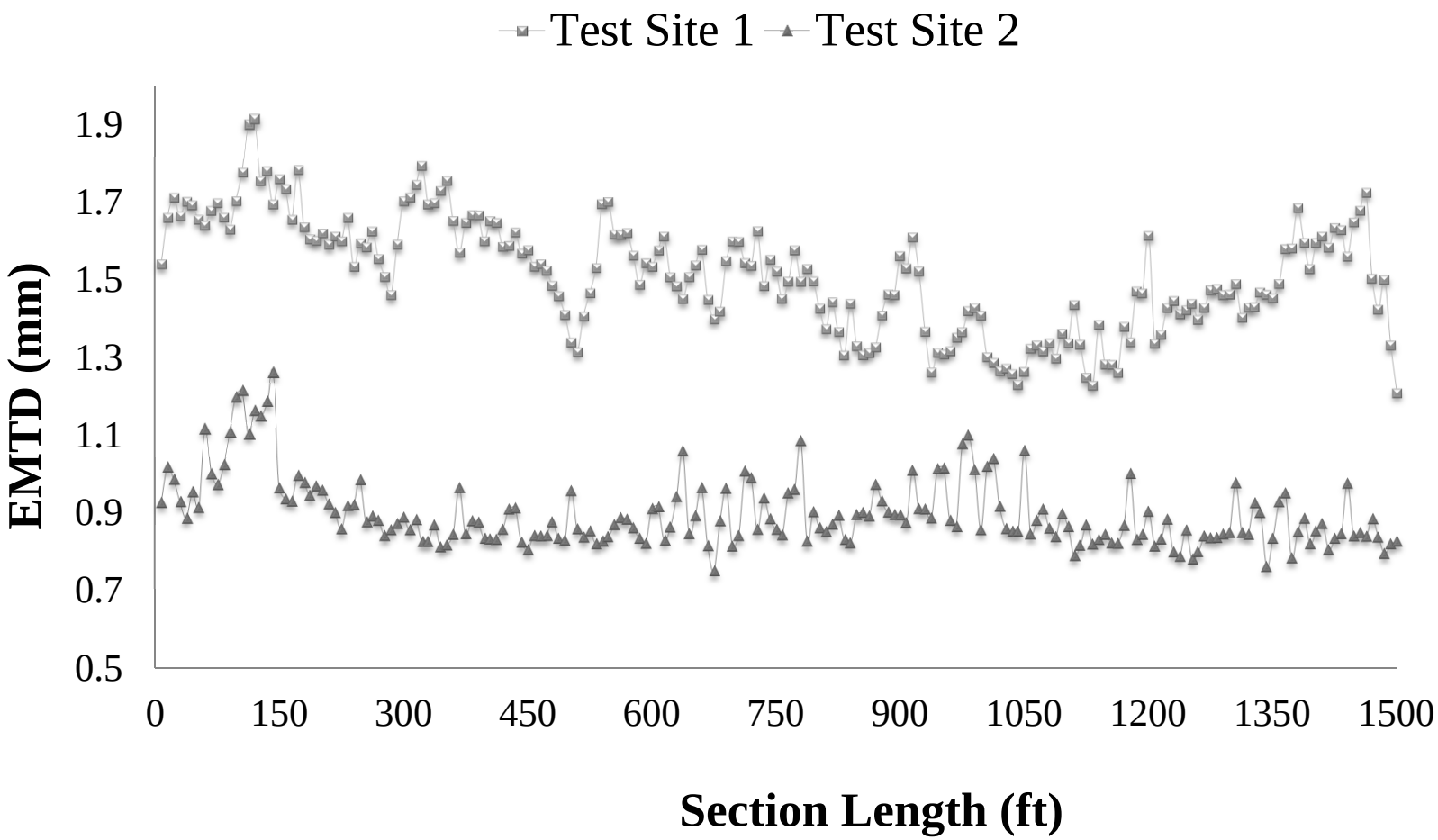
Comparison Analysis (15mph)



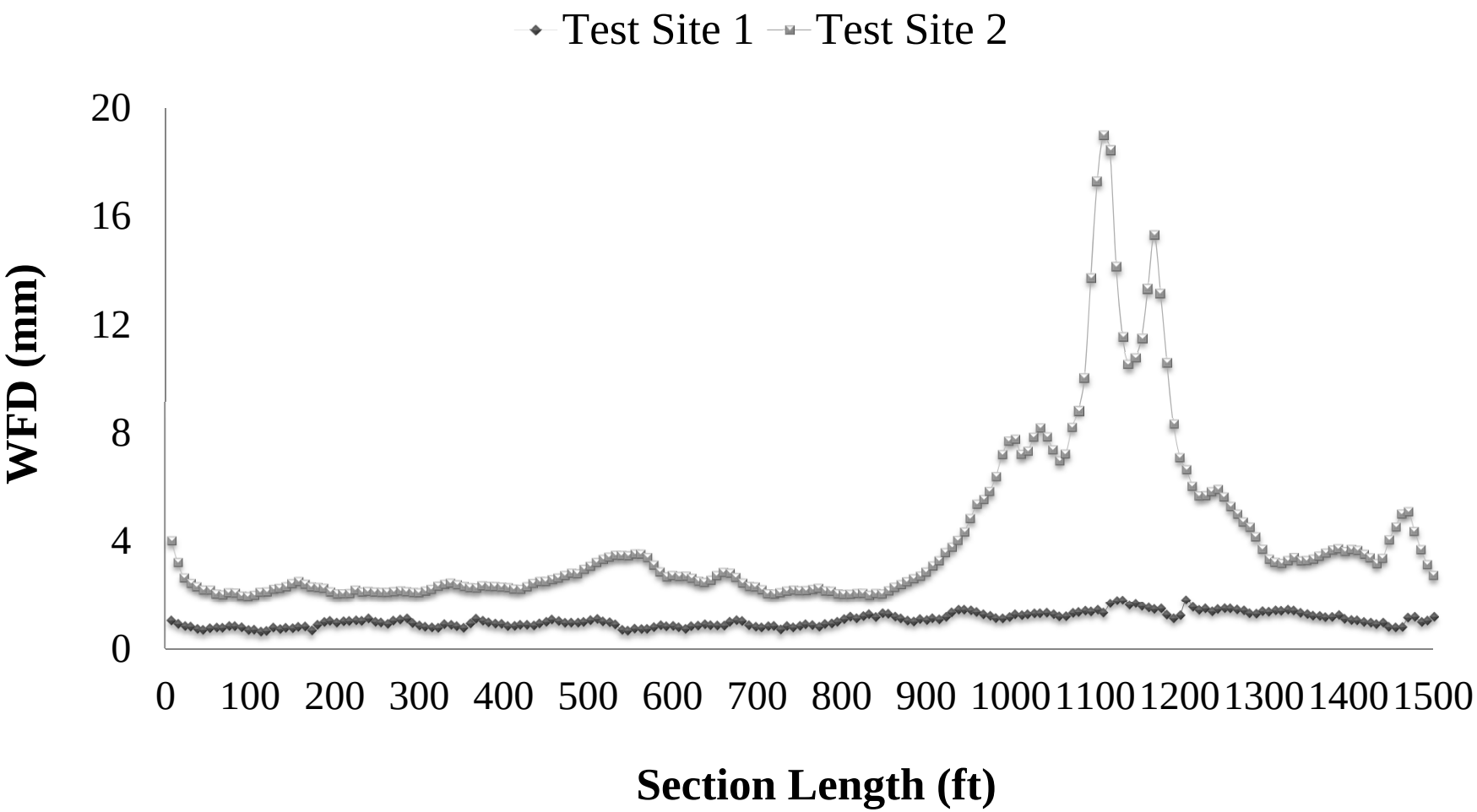
Drainage Evaluation

- Inertial Measurement Unit (IMU)
  - Consisting of accelerometers and fiber-optic gyroscopes
  - Collecting positioning, cross slope and vertical slope data
- PaveVision3D Texture Data
- Hydroplanning Speed Model
  - Water film depth: pavement type, cross slope, vertical grade, rain intensity

Drainage Evaluation Test Results



Drainage Evaluation Test Results



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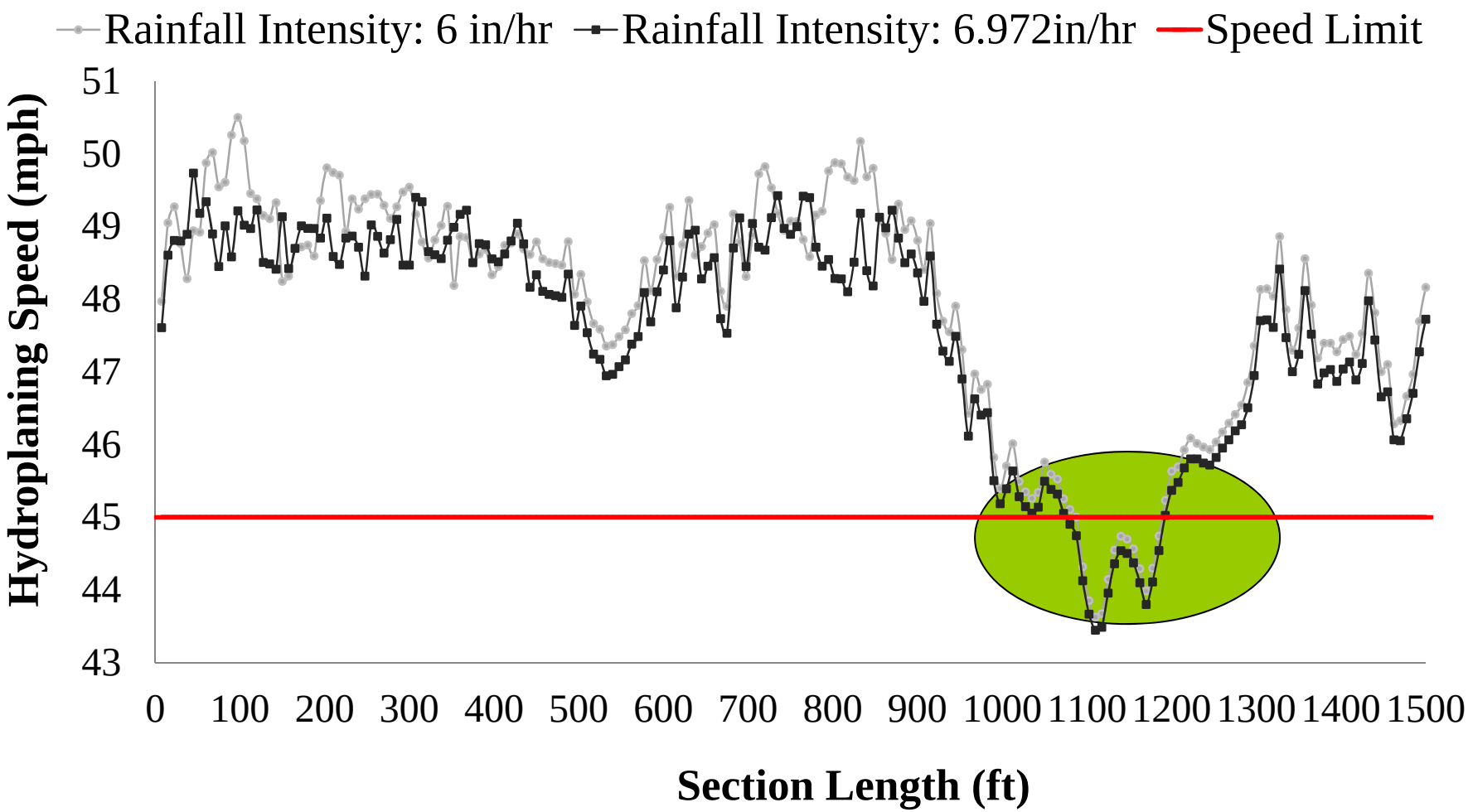


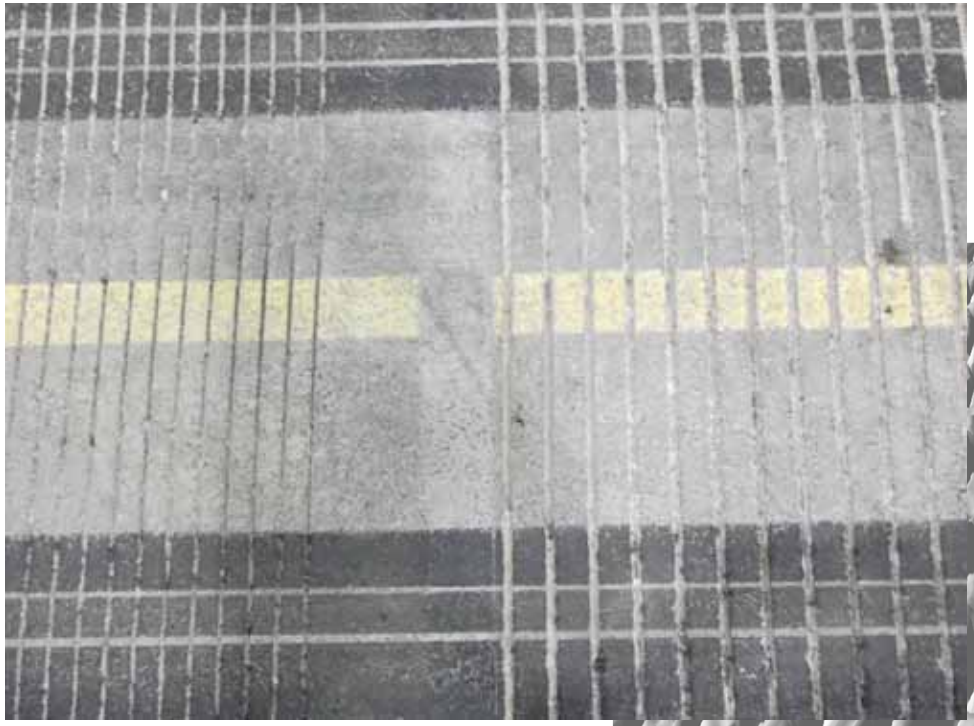
Grooves: Airfield & Highway Pavements

- Produces adequate skid resistance
- Prevents the occurrence of hydroplaning
- FAA Advisory Circular(AC) No. 150/5320-12C
  - Requirements for pavement groove dimension and performance
  - Needs to periodically evaluate runway groove performance
- Highway grooves
  - No standard

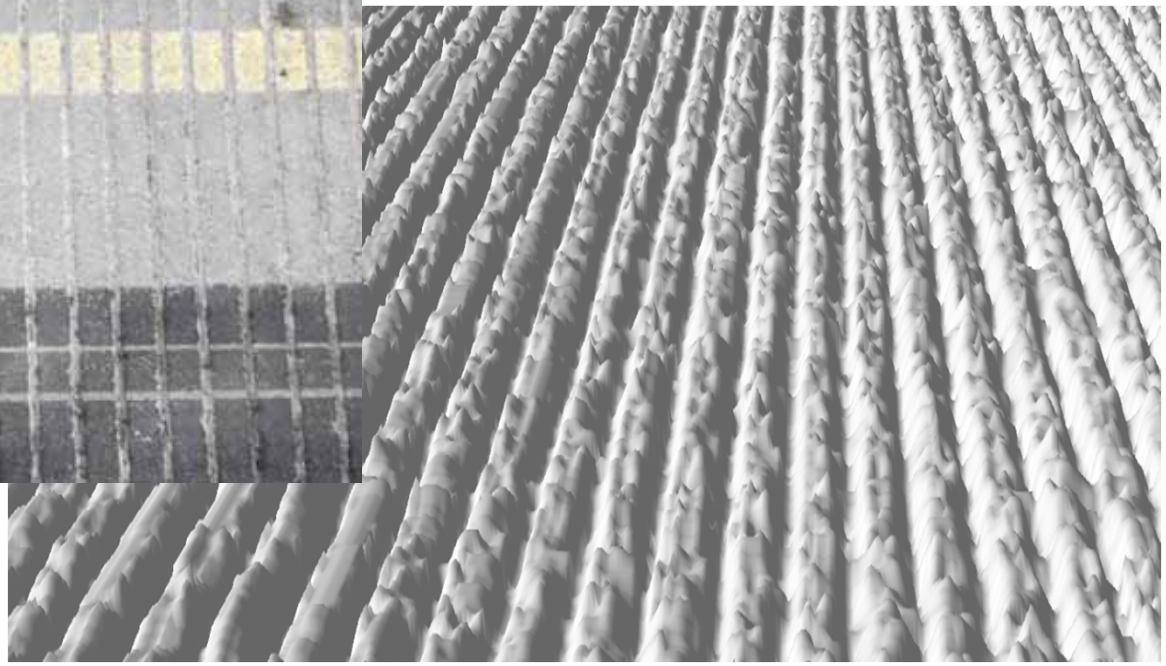
Groove Evaluation Approach

- To develop an algorithm to automatically estimate groove dimensions
  - Groove Depth
  - Groove Width, and
  - Groove Spacing
- To evaluate groove performance
  - Calculated groove dimensions
  - Groove configuration, and
  - Standard groove evaluation guidelines

Grooving

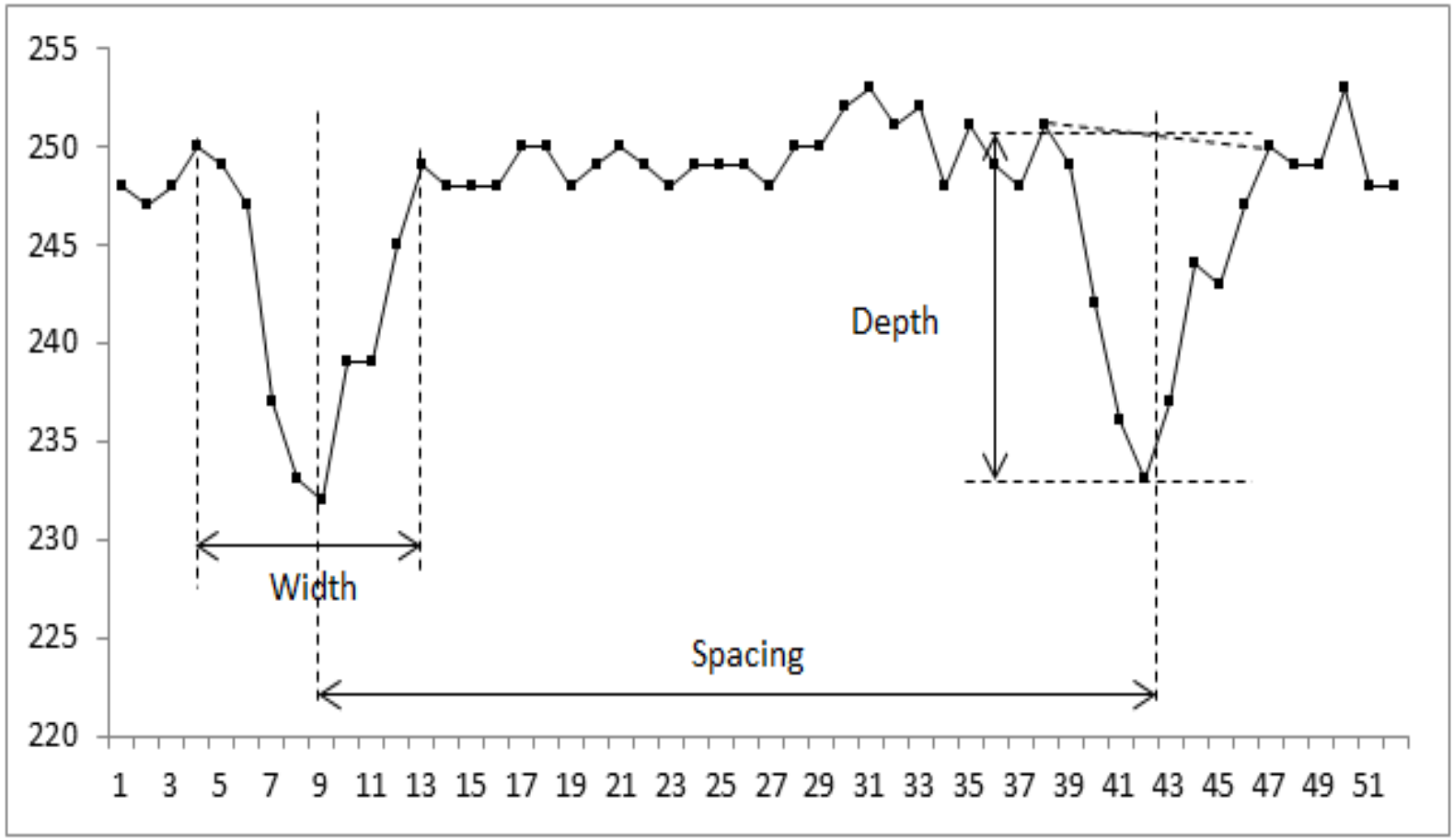


FAA NAPTF
(Transverse)

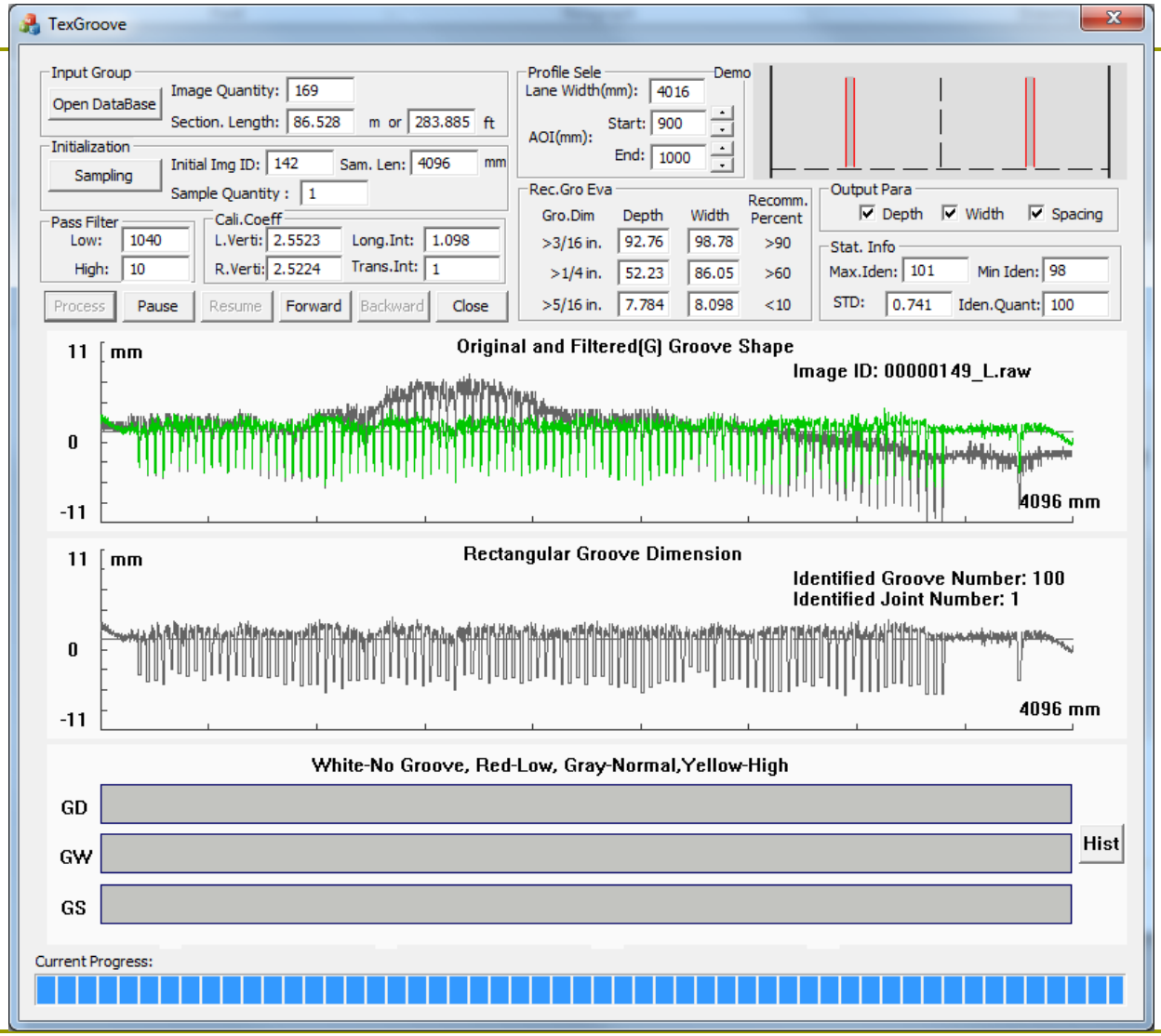


NGCS (Longitudinal)

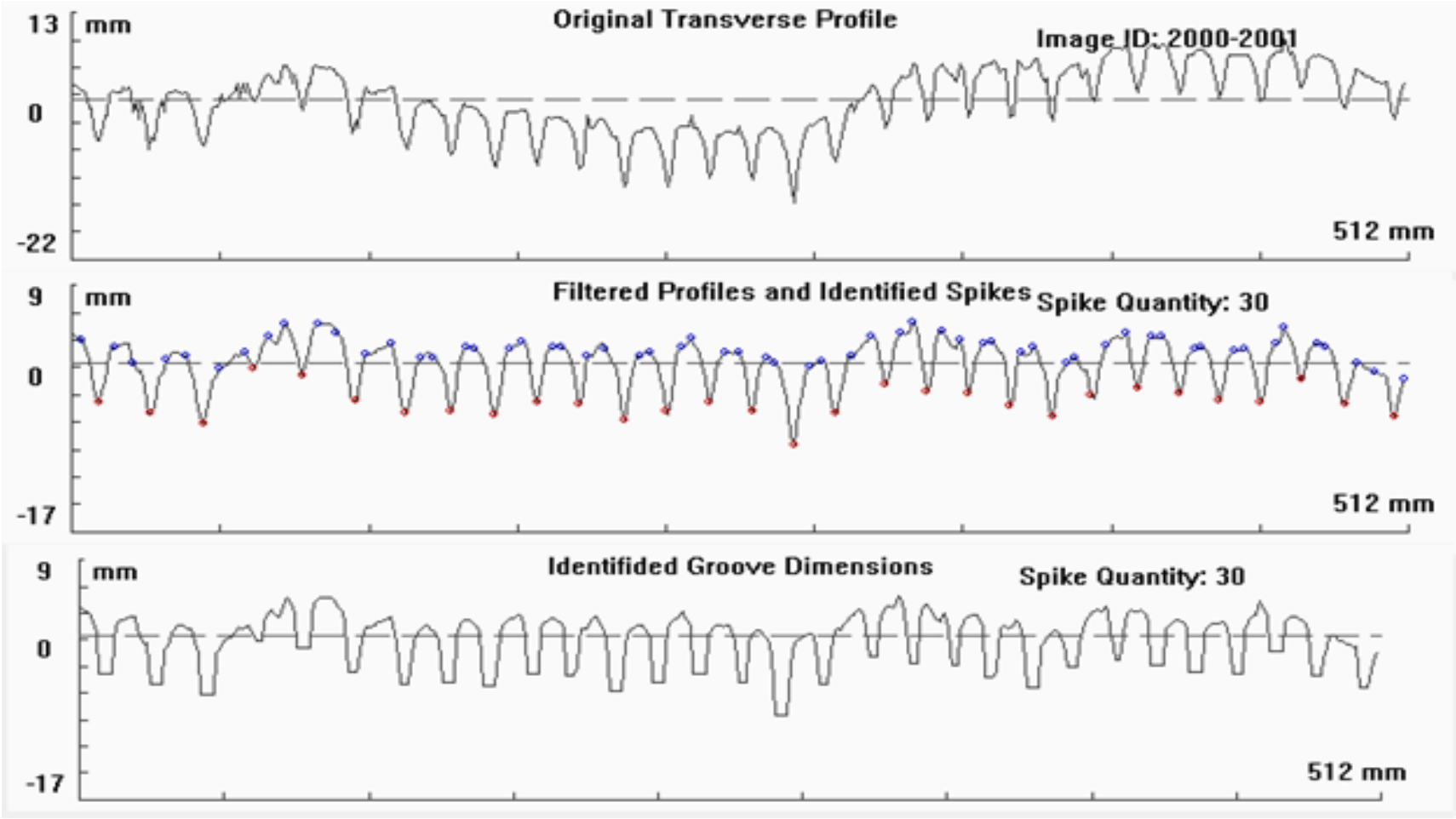
Groove Dimensions



Software Interface



Identification Results



Evaluation of AASHTO PP69-10

- Network Data Collection Using PaveVision3D Ultra
- Implement AASHTO PP69-10 Rutting Parameters
- Evaluate their Relationships and Propose a comprehensive Measure(s)

AASHTO PP69-10 Rutting Protocol

No.	Attribute	Acronym
1	Total Deformation Permillage	TDP
2	Left Deformation Permillage	LDP
3	Right Deformation Permillage	RDP
4	Left Rut Depth (mm)	LRD
5	Right Rut Depth (mm)	RRD
6	Left Rut Width (mm)	LRW
7	Right Rut Width (mm)	RRW
8	Left Rut Area (square mm)	LRA
9	Right Rut Area (square mm)	RRA
10	Total Number of Water Entrapment Points	TNW
11	Total Water Entrapment Depth (mm)	TWD
12	Total Water Entrapment Width (mm)	TWW

1mm Rutting Data

- Source
  - More than 100 miles NHS in AR
  - US65N and US70E
- 9000+ profiles
- Each profile 12 attributes
- Distribution of attributes
  - Slightly skewed or normally distributed

Evaluation Methodology

- Correlation Analysis
  - Examine preliminary relations
  - Correlation Matrix
- Linear Regression Analysis

Correlation Results

- Strong linear relations (correlation coefficient > 0.7):
  - TDP & LDP
  - TDP & RDP
  - LRD & LRA
  - RRD & RRA
- Weak linear relations (correlation coefficient <0.3)

Establish Quantitative Relations

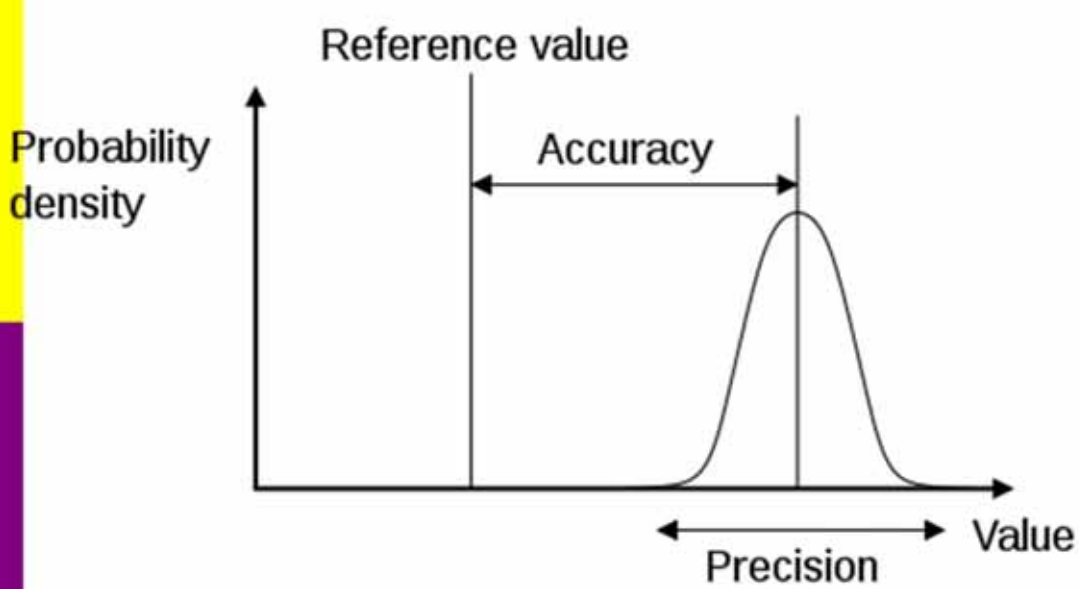
- Traditional Measures
  - Rutting depth (LRD & RRD)
- New Measures in PP69-10
  - Rutting width (LRW & RRW)
  - Rutting area (LRA & RRA)
  - Water related (TNW, TWD, & TWW)

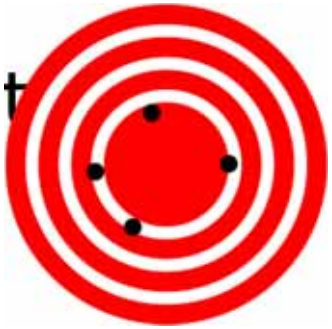
Regression Analysis Results

- Feasible and reliable to use rutting depth to predict rutting area measures
- Other attributes: not robust to predict with rutting depth

Variability, Precision, Accuracy

- Variability: Unevenness, Changeability
- Precision and Accuracy
- Reference Value and Probabilit





Good accuracy, Low precision

High precision, Low accuracy

Relating to Cracking Survey

- Variability & Precision
  - Target: small variability & tight range for high precision
- Reference & Accuracy
  - No good reference (Manual Survey?)
  - Accuracy: therefore in question
- Probability
  - Randomness?
- Accuracy: sometimes same as "bias"

Sources of Variability

- Complex pavement conditions
- Varying data collection methods
- Rater inconsistencies
- Inter-rater uniformity
- Time
- Transcription, referencing and data entry
- Varying protocol & expectations

Conclusion Remarks

- Sensor Technology: Completed
- Challenges to the Team & Industry: Software Solutions
  - To be beautiful, & also usable to pavement engineers
  - Confidence in quality of data
  - ME Design & PMS Apps