



# Ground Penetrating Radar Replacing Cores in Determining In-Place Density

2022 PAPA Conference, Hershey, PA  
January 19, 2022

Image Your World.



**PaveScan® RDM 2.0**

# Agenda

- History/What is it?
- Features
- Calibration using Cores
- Calibration using Pucks
- System QA Procedures
- Export Range
- Lane Extents
- PWL Report
- Linear and Area Defects
- Output – Google Earth

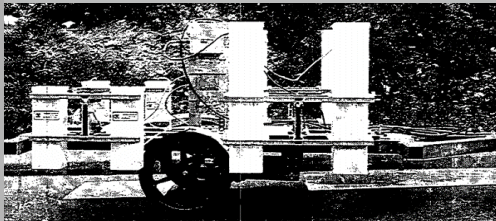


# History

How it started with the DOT/FHWA?



1992: SHRP1  
Initiative with  
TTI and GSSI



30 yrs: Pavement  
and Highway R&D

TTI, MnDOT, others  
with GSSI



2009: SHRP2 RO6C  
Initiative with

TTI/MnDOT and GSSI



# PaveScan RDM 2.0 – What is it?

PaveScan RDM 2.0

It is a complete **Continuous Full Coverage (CFC)** GPR system that will:

- Provide on-site dielectric values of newly laid and compacted asphalt
- Provide continuous full coverage density information
- Provide compaction information in real-time, on-site using a 2D map
- Provide coring locations
- Allow input of core information for calibration and back calculation of %compaction, %void content, and density



# PaveScan RDM 2.0 – What is it?

PaveScan RDM 2.0

Can be used as a:

- **Q/C Tool**
  - Roller Pattern Issues
  - Paver Issue
  - Number of Trucks Issue
  - Asphalt Issue
- **Q/A Tool**
  - PWL Reports
  - Google Earth Reports
- **Forensic Tool**



# PaveScan RDM 2.0 – What is it?

PaveScan RDM 2.0

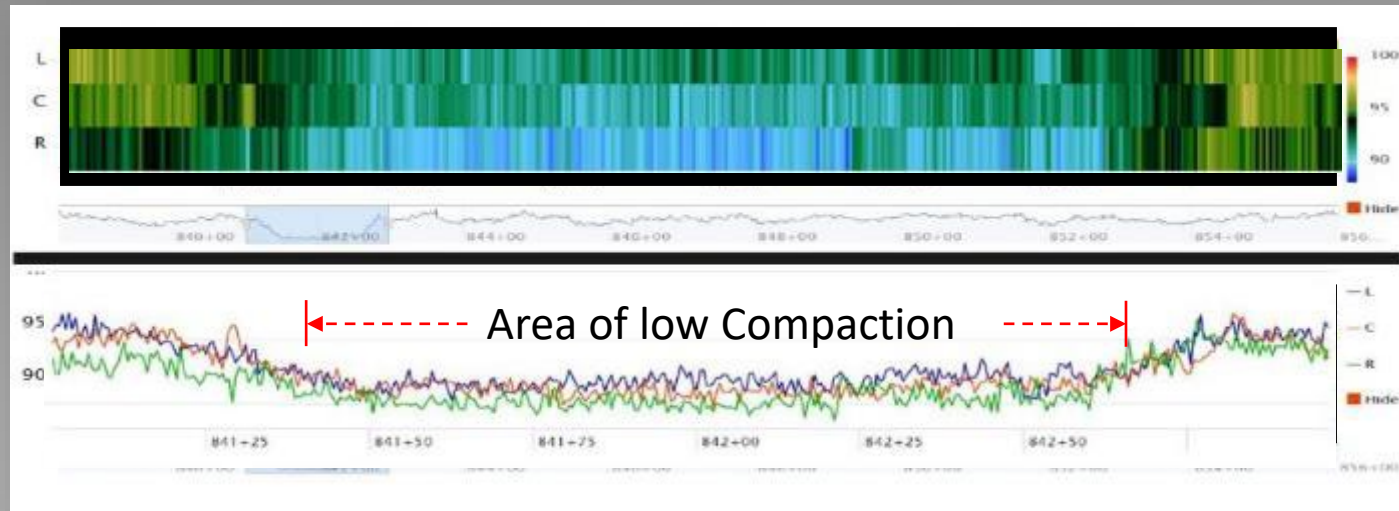
## Results:

- **DoTs: Save Money**
  - Maximize the Life of a Road
  - Reduce the Maintenance of Road
  - Increase Safety
- **Paving Contractors: Make Money**
  - Increase Pay Factor
  - Real-time intelligence for immediate decision making
  - Increase chances for winning contracts



# Features

PaveScan RDM 2.0



PaveScan RDM

Asphalt



Sub-Layer

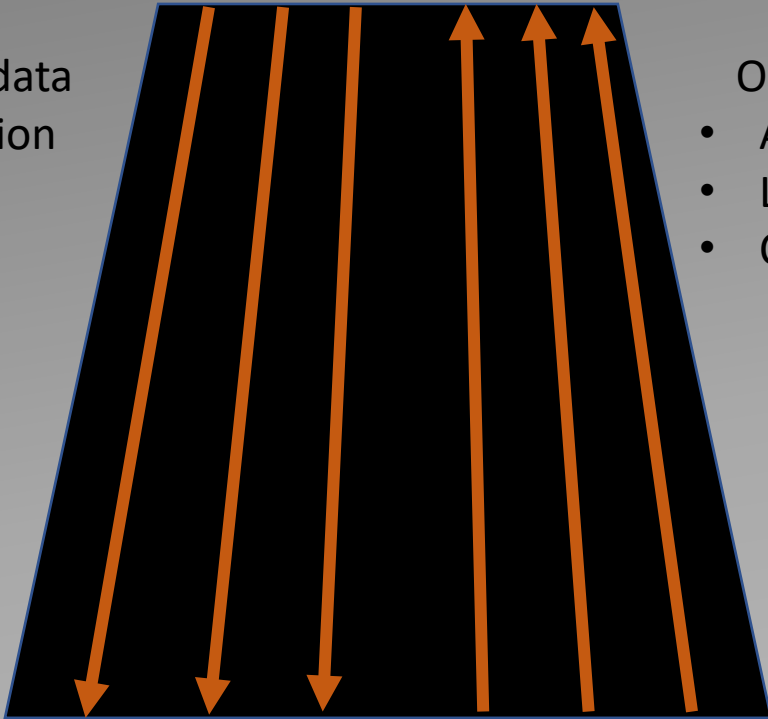
Air Voids



# Features

PaveScan RDM 2.0

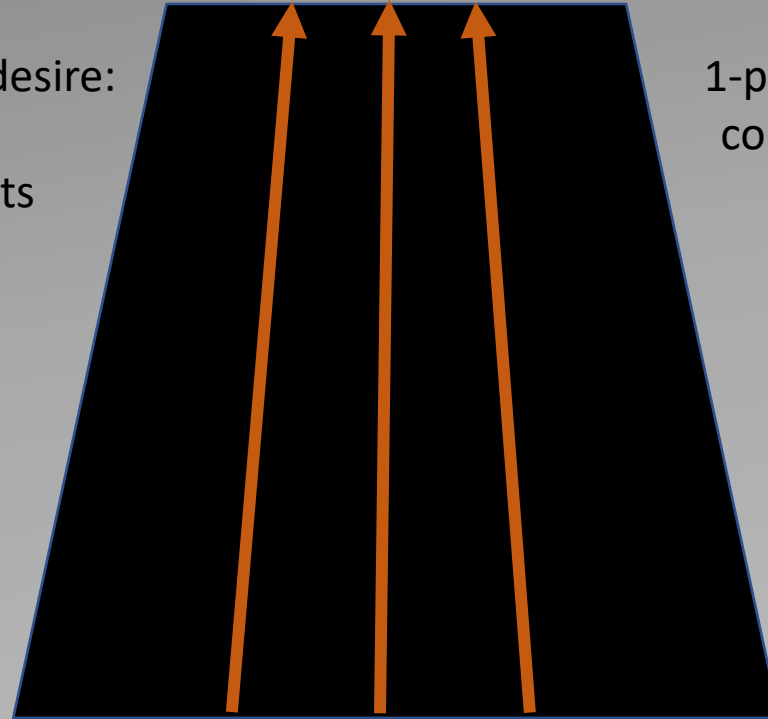
2-pass data collection



Or whatever you desire:

- Across the lane
- Longitudinal Joints
- Combination

1-pass data collection





# Calibration using Cores

PaveScan RDM 2.0

- Field Cores are used for the correlation of dielectric to density (% void or % compaction)
- Field cores can come from a test strip or after one day of on-site data collection
  
- Core locations are determined by the system or DOT
- Dielectric is taken at the core location PRIOR to coring
- Cores are taken to the lab for density measurement (% void or % compaction)

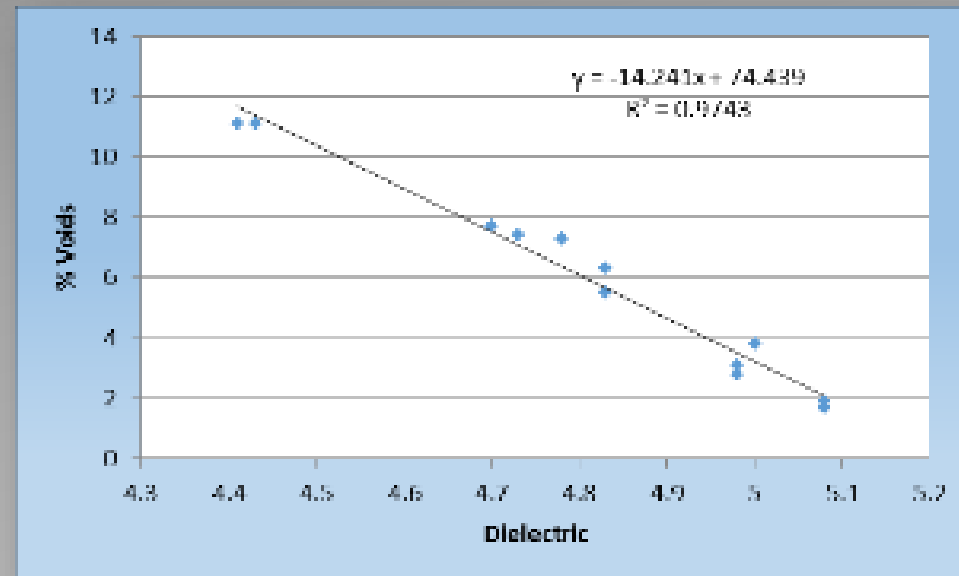


# Calibration using Cores

PaveScan RDM 2.0

Excel Example

Dielectric	% Voids
4.78	7.3
4.98	2.8
4.73	7.4
4.98	3.1
4.83	5.5
5.08	1.7
4.83	6.3
4.7	7.7
4.41	11.1
5.08	1.9
5	3.8
4.43	11.1



# Calibration using Pucks

PaveScan RDM 2.0

- In an effort to reduce (or even eliminate) coring, pucks\* can be used from the plants to calibrate the PaveScan RDM 2.0 system.
- Minimum of 3 pucks is recommended
- Each mix (calibration) is named and stored in the system and can be attached to a specific project.
- Future projects, if a mix was used in a prior job, can simply be attached to an existing calibration.

The screenshot displays the 'Input Information' screen for PaveScan RDM 2.0. The interface is dark-themed with white text. At the top, it says 'PaveScan RDM' and 'Warmup Complete'. Below this is a list of fields for data entry, each with a corresponding input box. The fields are: Name, Date Paved, Field ID (Test Summary Sheet #), Cumulative Daily Max Density (Tonnage), Bulk Specific Gravity (GMM), Temperature @ Gyration (Deg F), Agency Lab ID (Bituminous Mix #), Target Air Voids %, Sample ID, Tested Side (T - Top, B - Bottom), Air Void Content (%), Sample Thickness (mm), and Comments. At the bottom, there are two large orange buttons: 'Back' and 'Collect'.

Input Information

\* Other Terms – Pills, Biscuits, Bulks

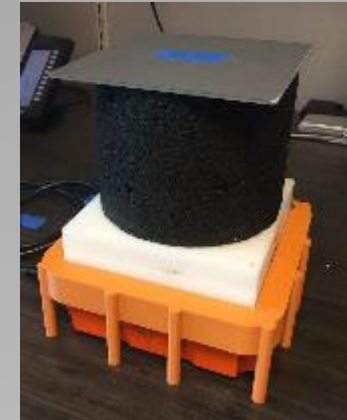


# Calibration using Pucks

PaveScan RDM 2.0



4-Step Process



# System QA Procedures

PaveScan RDM 2.0

Procedures were developed to assure the accuracy of the sensors.

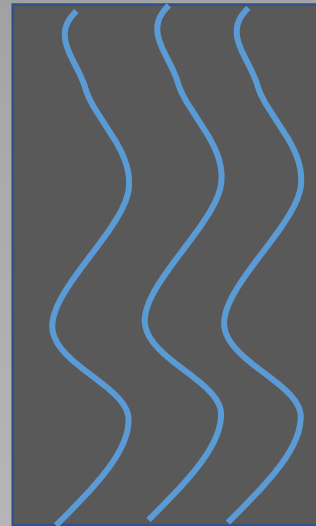
- HDPE Block
- Swerve Method
- Repeat Line Method

HDPE Block



Each Sensor, Dielectric =  $\sim 2.35$ ,  $\pm .05$

Swerve Method



1. Suggested On-Site, walk about 250 feet using a swerve pattern
2. Outside sensors no closer than 1 foot from the longitudinal joint
3. Turn around and walk back 250 feet using the swerve pattern
4. Dielectric of sensors should be about .05 of each other

Repeat Line Method



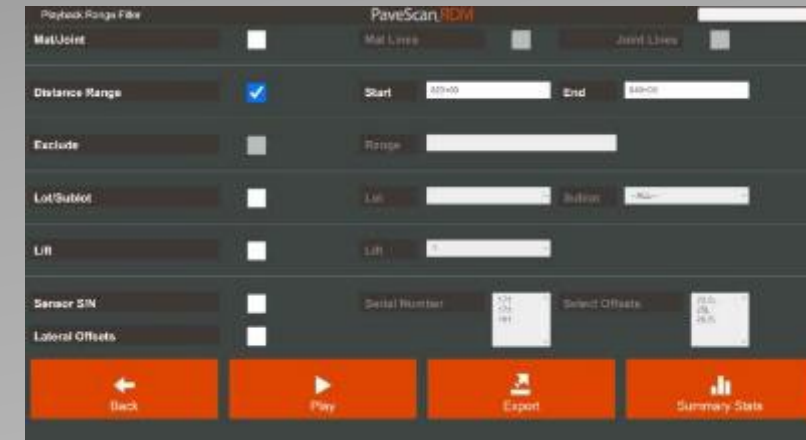
1. Suggested On-Site, draw a single line about 6-10 feet across the lane
2. Walk each sensor, one at a time, *perfectly* along the line
3. Dielectric of sensors should be about .05 of each other



# Export Range

PaveScan RDM 2.0

Throughout the day or project, multiple data files are collected and saved. This feature allows the user to combine chosen files to create a single file.



Playback Range screens allow the user to select which files to combine for displaying and exporting.



# Lane Extents

PaveScan RDM 2.0

The user has an option to define lane extents for each lane.

- Near and Far Offset Distance
- Near and Far Joint Type

This information is used if using the PWL option.

Lane #	Near Offset Dist	Near Offset Joint Type	Far Offset Dist	Far Offset Joint Type
1	<input type="text" value="Enter Value"/>	Confined	<input type="text" value="Enter Value"/>	Confined
2	<input type="text" value="Enter Value"/>	Confined	<input type="text" value="Enter Value"/>	Confined
3	<input type="text" value="Enter Value"/>	Confined	<input type="text" value="Enter Value"/>	Confined
4	<input type="text" value="Enter Value"/>	Confined	<input type="text" value="Enter Value"/>	Confined
5	<input type="text" value="Enter Value"/>	Confined	<input type="text" value="Enter Value"/>	Confined
6	<input type="text" value="Enter Value"/>	Confined	<input type="text" value="Enter Value"/>	Confined
7	<input type="text" value="Enter Value"/>	Confined	<input type="text" value="Enter Value"/>	Confined
8	<input type="text" value="Enter Value"/>	Confined	<input type="text" value="Enter Value"/>	Confined



# PWL Reports

PaveScan RDM 2.0

The user has an option to produce PWL reports by entering user specified limits that will be used to produce the reports.

Report Options

Mat PWL Upper Limit (Dist.) 0

Mat PWL Lower Limit (Dist.) 0

Joint PWL Upper Limit (Dist.) 0

Joint PWL Lower Limit (Dist.) 0

Joint Line Max. Dist. from Closest Lane Extent (ft) 0

Mat Line Min. Dist. from Closest Lane Extent (ft) 0

Histogram Bin Interval (Dist.) 0

Histogram Maximum Value (Dist.) 0

Histogram Minimum Value (Dist.) 0

Back Save

User-selected upper and lower limits

Summary Statistics

Distance Range	Start Station	End Station	Min. Lat Offset	Max. Lat Offset	Mat PWL	Joint PWL	Mat Median	Joint Median	Mat St Dev	Joint St Dev
Segment	728+00	730+00	12L	24L	0	36.66	0	4.36	0	0.13
Segment	730+00	740+00	12L	24L	0	27.47	0	4.01	0	0.10
Segment	740+00	741+00	12L	24L	0	61.34	0	4.33	0	0.14
Segment	741+00	742+00	12L	24L	0	61.54	0	4.33	0	0.14
Segment	731+00*	732+00	24L	36L	12.0	0	4.7	0	0.15	0
Segment	732+00	733+00	24L	36L	5.89	0	4.74	0	0.17	0
Segment	733+00	734+00	24L	36L	20.38	0	4.8	0	0.18	0
Segment	734+00	735+00	24L	36L	14.50	0	4.78	0	0.14	0
Segment	735+00	736+00	24L	36L	0.0	0	4.71	0	0.17	0
Segment	728+00	737+00	24L	36L	28.07	0	4.81	0	0.2	0
Total	721+00	071+00	12L	36L	40.7	10.00	4.67	4.01	0.19	0.10

Back

Displayed Report





# PWL Reports

PaveScan RDM 2.0

Exported PWL Reports (.csv format)

1. ADM Export Histogram Data Statistics  
2. Project Name: THRD\_11\_2020-07-27\_RDM2  
3. Project Location: CA  
4. Equipment Operator: GK  
5. Comments  
6. Lift: 1  
7. Reference Line  
8. Calibration Mile  
9. Project ID  
10. Route Designation  
11. Material  
12. Disabled Highway No  
13. Date Paved  
14. Mat PWL Lower Limit Dielectric: 4.30  
15. Mat PWL Upper Limit Dielectric: 4.90  
16. Joint PWL Lower Limit Dielectric: 4.30  
17. Joint PWL Upper Limit Dielectric: 4.90  
18. Joint Line Min. Dist. from closed lane extent (ft): 1.20  
19. Joint Line Max. Dist. from closed lane extent (ft): 6.75

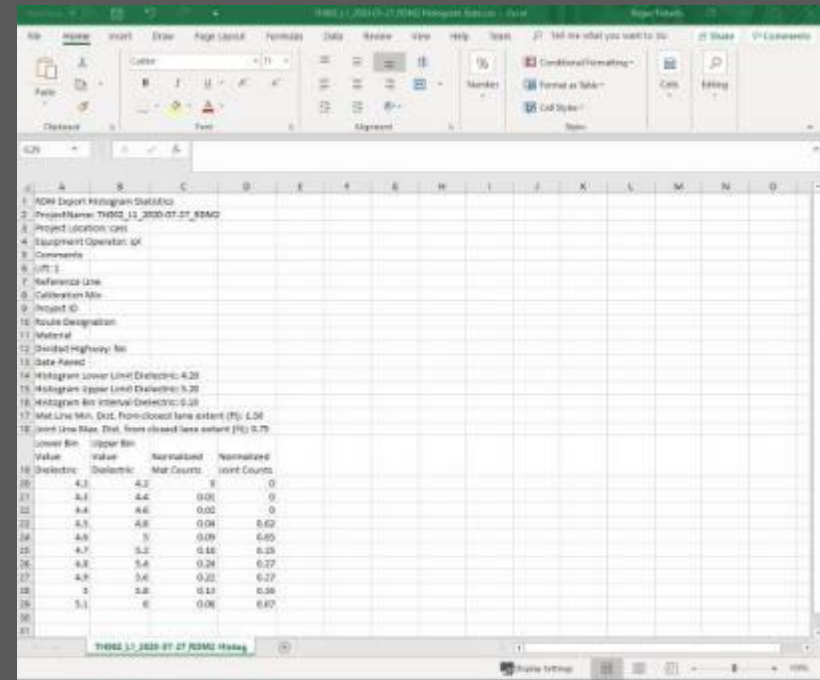
Start	End	Min	Max	Median	StdDev							
20 (ft)	Distance	Distance	Start	End	Min	Max	Median	StdDev	Lower Bin	Upper Bin		
21	8818.8	8848	8848.9	8848.9	36	36	40.15	0	4.89	0	0.2	0
22	8849	8888	8888.9	8888.9	24	36	41.94	0	4.89	0	0.2	0
23	8889	8928	8928.9	8928.9	24	36	48.99	0	4.93	0	0.11	0
24	8929	8968	8968.9	8968.9	24	36	31.14	0	4.87	0	0.15	0
25	8969	9008	9008.9	9008.9	24	36	31.75	0	4.87	0	0.16	0
26	9009	9048	9048.9	9048.9	24	36	31.75	0	4.87	0	0.16	0
27	9049	9088	9088.9	9088.9	24	36	31	0	4.94	0	0.19	0
28	9089	9128	9128.9	9128.9	24	36	31.74	0	4.89	0	0.16	0
29	9129	9168	9168.9	9168.9	24	36	31.48	0	4.86	0	0.16	0
30	9169	9208	9208.9	9208.9	24	36	36.87	0	4.87	0	0.11	0
31	9209	9248	9248.9	9248.9	24	36	40.76	0	4.93	0	0.19	0
32	9249	9288	9288.9	9288.9	24	36	30.42	0	4.88	0	0.16	0
33	9289	9328	9328.9	9328.9	24	36	30.42	0	4.88	0	0.16	0
34	9329	9368	9368.9	9368.9	24	36	30.42	0	4.88	0	0.16	0
35	9369	9408	9408.9	9408.9	24	36	30.42	0	4.88	0	0.16	0
36	9409	9448	9448.9	9448.9	24	36	30.42	0	4.88	0	0.16	0
37	9449	9488	9488.9	9488.9	24	36	30.42	0	4.88	0	0.16	0
38	9489	9528	9528.9	9528.9	24	36	30.42	0	4.88	0	0.16	0
39	9529	9568	9568.9	9568.9	24	36	30.42	0	4.88	0	0.16	0
40	9569	9608	9608.9	9608.9	24	36	30.42	0	4.88	0	0.16	0
41	9609	9648	9648.9	9648.9	24	36	30.42	0	4.88	0	0.16	0
42	9649	9688	9688.9	9688.9	24	36	30.42	0	4.88	0	0.16	0
43	9689	9728	9728.9	9728.9	24	36	30.42	0	4.88	0	0.16	0
44	9729	9768	9768.9	9768.9	24	36	30.42	0	4.88	0	0.16	0
45	9769	9808	9808.9	9808.9	24	36	30.42	0	4.88	0	0.16	0
46	9809	9848	9848.9	9848.9	24	36	30.42	0	4.88	0	0.16	0
47	9849	9888	9888.9	9888.9	24	36	30.42	0	4.88	0	0.16	0
48	9889	9928	9928.9	9928.9	24	36	30.42	0	4.88	0	0.16	0
49	9929	9968	9968.9	9968.9	24	36	30.42	0	4.88	0	0.16	0
50	9969	10008	10008.9	10008.9	24	36	30.42	0	4.88	0	0.16	0

Mat & Joint PWL, Median Values, and Standard Deviation for each segment

1. ADM Export Combined PWL Statistics  
2. Project Name: THRD\_11\_2020-07-27\_RDM2  
3. Project Location: CA  
4. Equipment Operator: GK  
5. Comments  
6. Lift: 1  
7. Reference Line  
8. Calibration Mile  
9. Project ID  
10. Route Designation  
11. Material  
12. Disabled Highway No  
13. Date Paved  
14. Mat PWL Lower Limit Dielectric: 4.30  
15. Mat PWL Upper Limit Dielectric: 4.90  
16. Joint PWL Lower Limit Dielectric: 4.30  
17. Joint PWL Upper Limit Dielectric: 4.90  
18. Joint Line Min. Dist. from closed lane extent (ft): 1.20  
19. Joint Line Max. Dist. from closed lane extent (ft): 6.75

Distance	Start	End	Min	Max	Median	StdDev	Joint Dielectric	
20 (ft)	Distance	Distance	Start	End	Min <td>Max<td>Median<td>StdDev</td></td></td>	Max <td>Median<td>StdDev</td></td>	Median <td>StdDev</td>	StdDev
21	8818.8	8848	8848.9	8848.9	36	36	40.15	0
22	8849	8888	8888.9	8888.9	24	36	41.94	0
23	8889	8928	8928.9	8928.9	24	36	48.99	0
24	8929	8968	8968.9	8968.9	24	36	31.14	0
25	8969	9008	9008.9	9008.9	24	36	31.75	0
26	9009	9048	9048.9	9048.9	24	36	31.75	0
27	9049	9088	9088.9	9088.9	24	36	31	0
28	9089	9128	9128.9	9128.9	24	36	31.74	0
29	9129	9168	9168.9	9168.9	24	36	31.48	0
30	9169	9208	9208.9	9208.9	24	36	36.87	0
31	9209	9248	9248.9	9248.9	24	36	40.76	0
32	9249	9288	9288.9	9288.9	24	36	30.42	0
33	9289	9328	9328.9	9328.9	24	36	30.42	0
34	9329	9368	9368.9	9368.9	24	36	30.42	0
35	9369	9408	9408.9	9408.9	24	36	30.42	0
36	9409	9448	9448.9	9448.9	24	36	30.42	0
37	9449	9488	9488.9	9488.9	24	36	30.42	0
38	9489	9528	9528.9	9528.9	24	36	30.42	0
39	9529	9568	9568.9	9568.9	24	36	30.42	0
40	9569	9608	9608.9	9608.9	24	36	30.42	0
41	9609	9648	9648.9	9648.9	24	36	30.42	0
42	9649	9688	9688.9	9688.9	24	36	30.42	0
43	9689	9728	9728.9	9728.9	24	36	30.42	0
44	9729	9768	9768.9	9768.9	24	36	30.42	0
45	9769	9808	9808.9	9808.9	24	36	30.42	0
46	9809	9848	9848.9	9848.9	24	36	30.42	0
47	9849	9888	9888.9	9888.9	24	36	30.42	0
48	9889	9928	9928.9	9928.9	24	36	30.42	0
49	9929	9968	9968.9	9968.9	24	36	30.42	0
50	9969	10008	10008.9	10008.9	24	36	30.42	0

Summary Statistics for mat and joint measurements for the entire project



Histogram distribution of values



# Linear and Area Defects

PaveScan RDM 2.0

If checked, all defects are exported to .csv and .kml files

Value Type	Value
Dielectric less than	4.5
Percent Voids greater than	8
Percent Compaction less than	92
Density less than	4
Linear dist. greater than or equal to	4
Area greater than or equal to	8

Back Save

User-selected criteria



# Linear and Area Defects

PaveScan RDM 2.0

Exported Reports (.csv format)

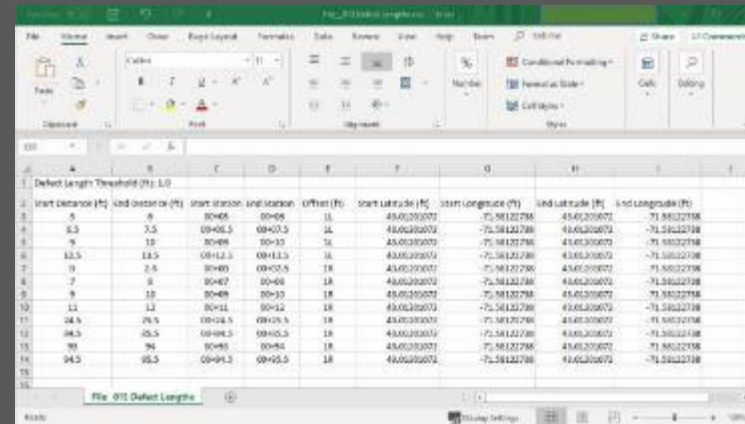


The screenshot shows an Excel spreadsheet titled "File Segment Defect Summary". The data is as follows:

Defect threshold (%)	Completion	# of Defects
2.00	32.06	180
2.00	32.06	180

Below the table, there are fields for "Start Distance (ft)", "Start Station", "Segment Length (ft)", "# of Defects", "Measure # of Defects", "% Defective", and "Straddles adjacent Segment".

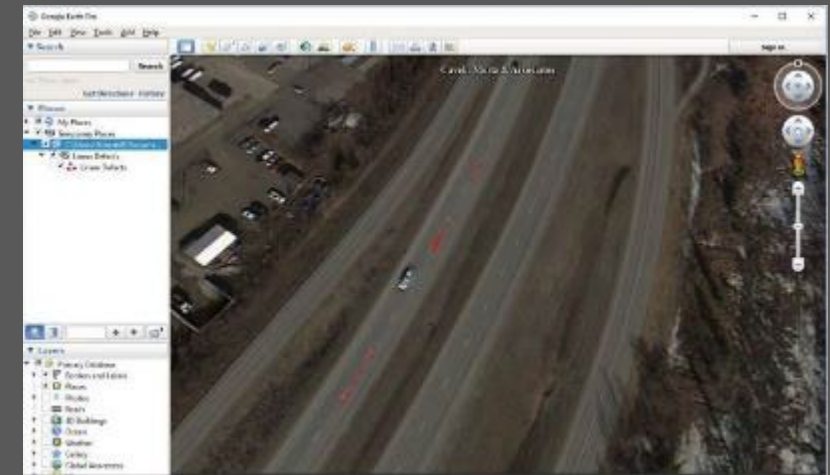
Segment Summary



The screenshot shows an Excel spreadsheet titled "File 010 Defect Lengths". The data is as follows:

Start Distance (ft)	End Distance (ft)	Start Station	End Station	Offset (ft)	Start Latitude (N)	Start Longitude (W)	End Latitude (N)	End Longitude (W)
5	8	80+08	80+08	1L	48.0020000	-71.5812278	48.0020000	-71.5812278
8.5	3.5	09+08.5	09+03.5	2L	48.0020000	-71.5812278	48.0020000	-71.5812278
9	10	80+08	80+10	2L	48.0020000	-71.5812278	48.0020000	-71.5812278
12.5	12.5	09+12.5	09+12.5	2L	48.0020000	-71.5812278	48.0020000	-71.5812278
13	2.5	80+00	09+02.5	1R	48.0020000	-71.5812278	48.0020000	-71.5812278
7	8	80+07	80+08	1R	48.0020000	-71.5812278	48.0020000	-71.5812278
9	10	80+08	80+10	1R	48.0020000	-71.5812278	48.0020000	-71.5812278
11	12	80+11	80+12	1R	48.0020000	-71.5812278	48.0020000	-71.5812278
24.5	24.5	09+24.5	09+24.5	1R	48.0020000	-71.5812278	48.0020000	-71.5812278
38.5	38.5	09+38.5	09+38.5	1R	48.0020000	-71.5812278	48.0020000	-71.5812278
39	34	80+39	80+34	1R	48.0020000	-71.5812278	48.0020000	-71.5812278
94.5	95.5	09+94.5	09+95.5	1R	48.0020000	-71.5812278	48.0020000	-71.5812278

Linear Defect File



KML File (display using Google Earth)



# Deployment Options

PaveScan RDM 2.0



Vehicle (Van, Golf Cart...)



Segway

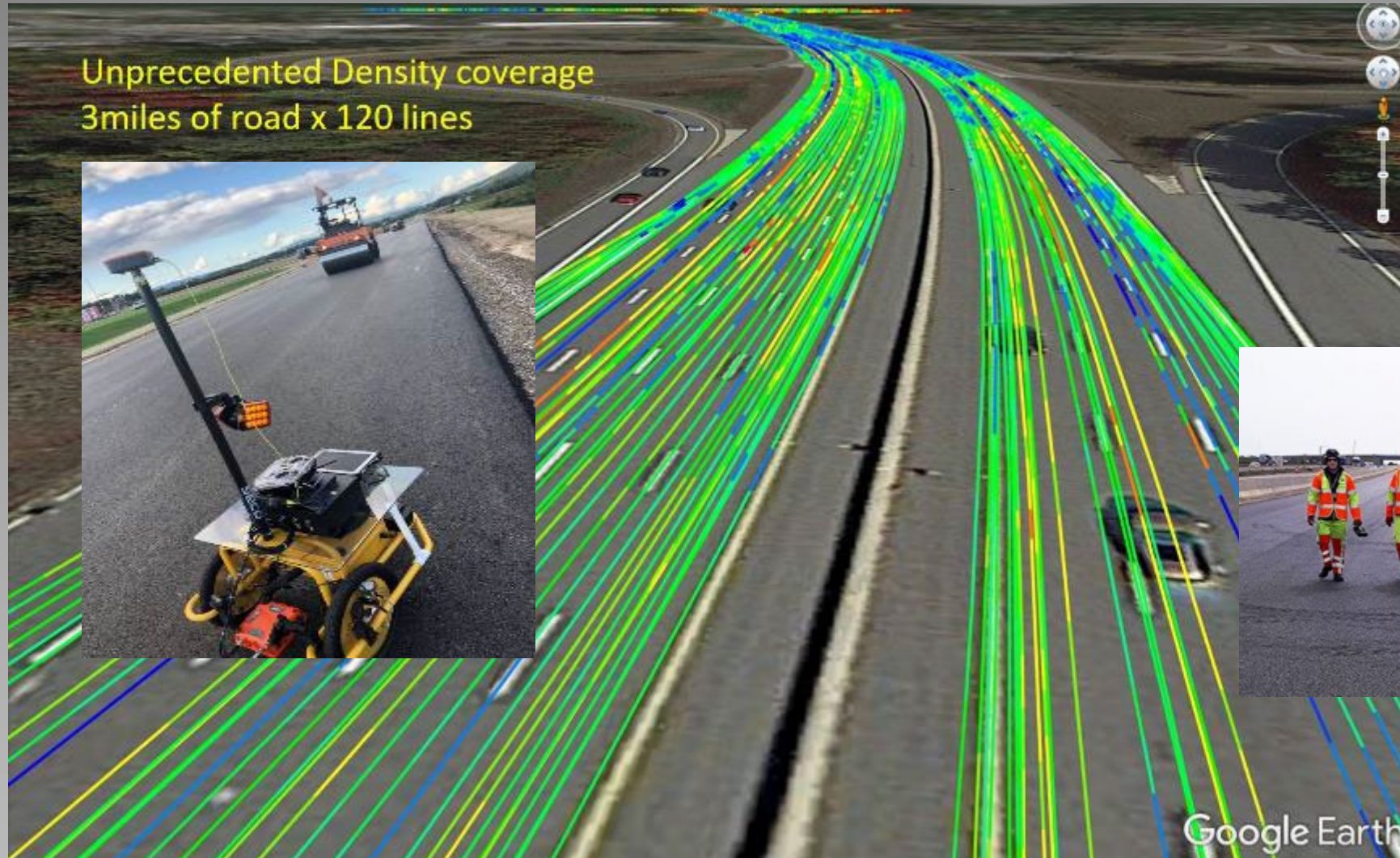


Robot



# Deployment Options

PaveScan RDM 2.0

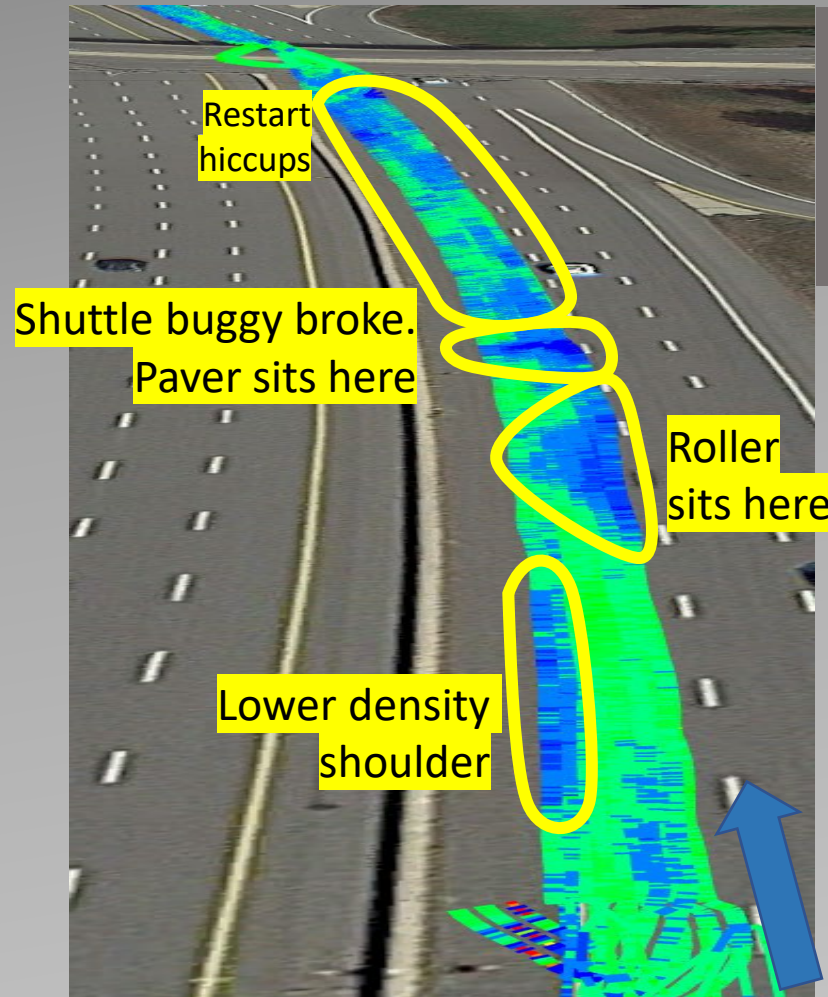


# KML file (Google Earth)

PaveScan RDM 2.0

## Examples

Densities correlate to known issues which can be mapped and perhaps rolled out.



1000ft section  
12 lines = 2mi.  
of GPR data  
~50k points



# Questions

PaveScan RDM 2.0

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Thank You!!

