



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

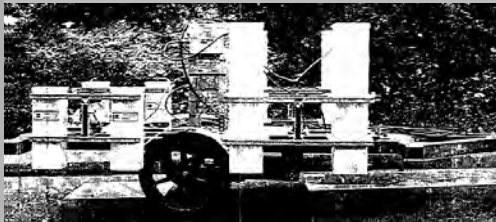


History

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**



Features

PaveScan RDM 2.0

Rugged Deployment Cart

- Modular assembly for easy deployment and transport
- Foldable deployment arms with high-visibility for work site safety
- Foot-activated brake on rear wheel
- Easy to attach and remove sensors



Integrated Concentrator Box

- Accommodates up to 3 sensors
- Housing for cable management
- Hot-swappable, dual batteries

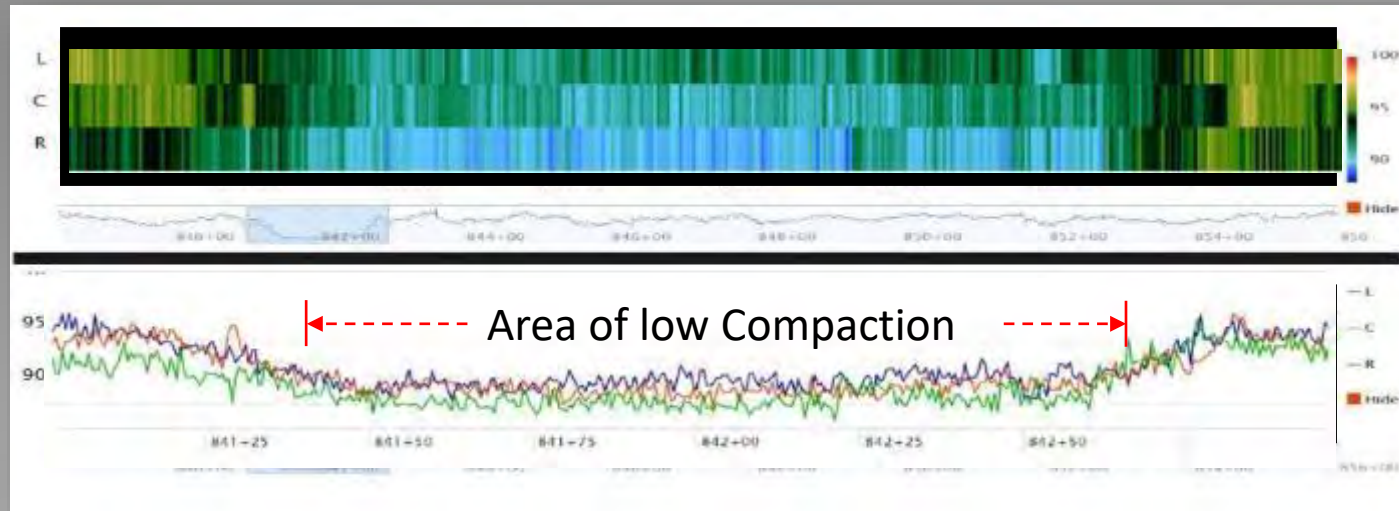
Sensor Design

- Built specifically for the extremes of the asphalt paving environment
- Green laser to aid in location accuracy and collection guide



Features

PaveScan RDM 2.0



PaveScan RDM

Asphalt

Sub-Layer



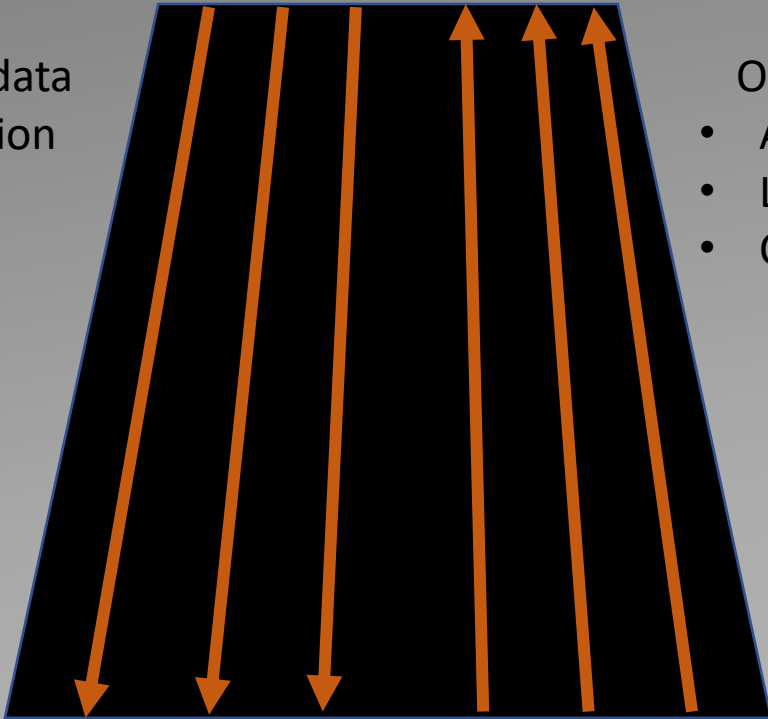
Air Voids



Features

PaveScan RDM 2.0

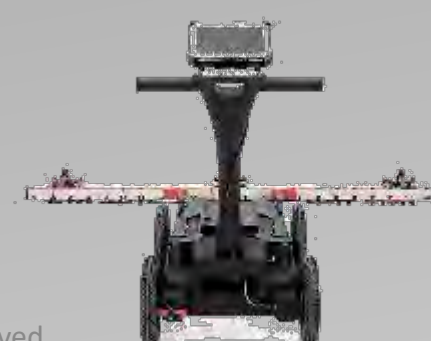
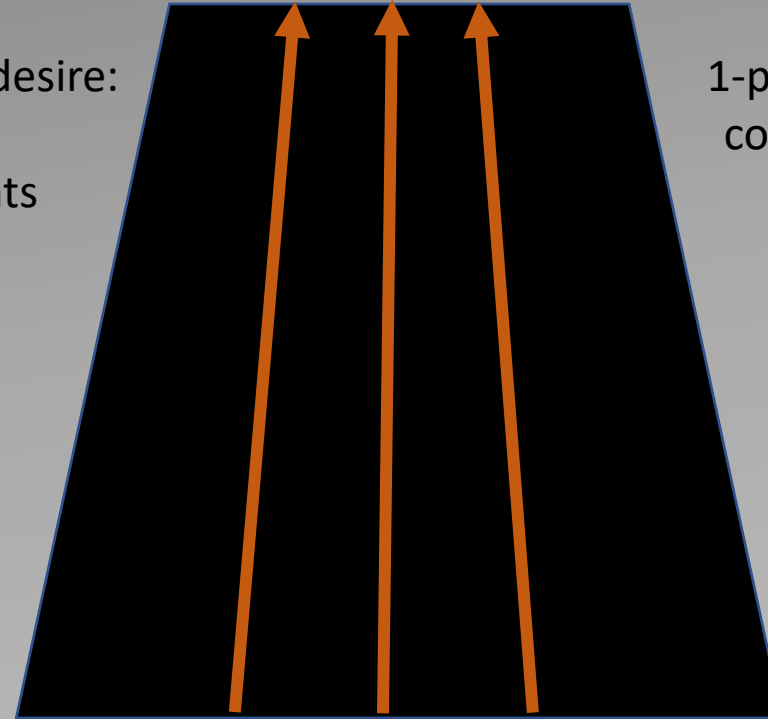
2-pass data collection



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

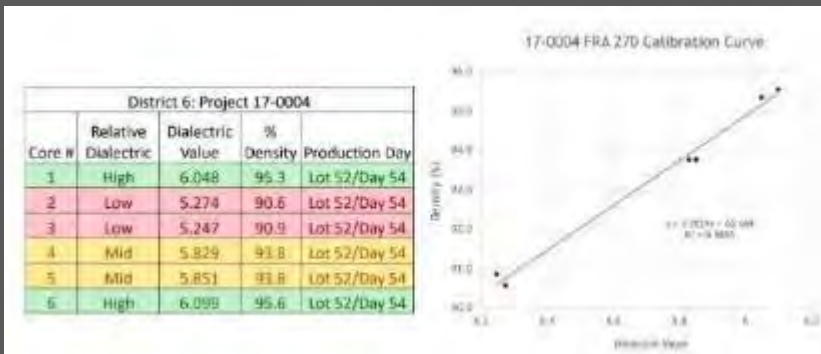
- Core locations are determined by the system or DOT
- Dielectric is taken at the core location PRIOR to coring
- Cores are taken to the lab for density measurement (% void or % compaction)



Calibration using Cores

PaveScan RDM 2.0

Values are entered into the system



Courtesy Ohio DOT

Core Calibration

Core Calibration Filename: Select Calibration File

Core Measurement Type: Specify Measurement Type

A Value: 1.0000

B Value: 0.0000

GMM: 0.0000

Mix Info: 0.0000

R-Squared Fit: 0.0000

Core Calibration Equation: Select Calibration Equation Type

Buttons: Back, New Calibration, Call from Core, Save

Core Calibration

Core #	Relative Dielectric	% Density
1	6.048	95.3
2	5.274	90.6
3	5.247	90.9
4	5.829	93.8
5	5.851	93.8
6	6.099	95.6

Buttons: Back, New Calibration, Call A.A.R, Save

- Multiple mixes can be entered, named, and saved onto the system.
- Every project can have a specific mix calibration attached to it, even for day-to-day changes of mixes.

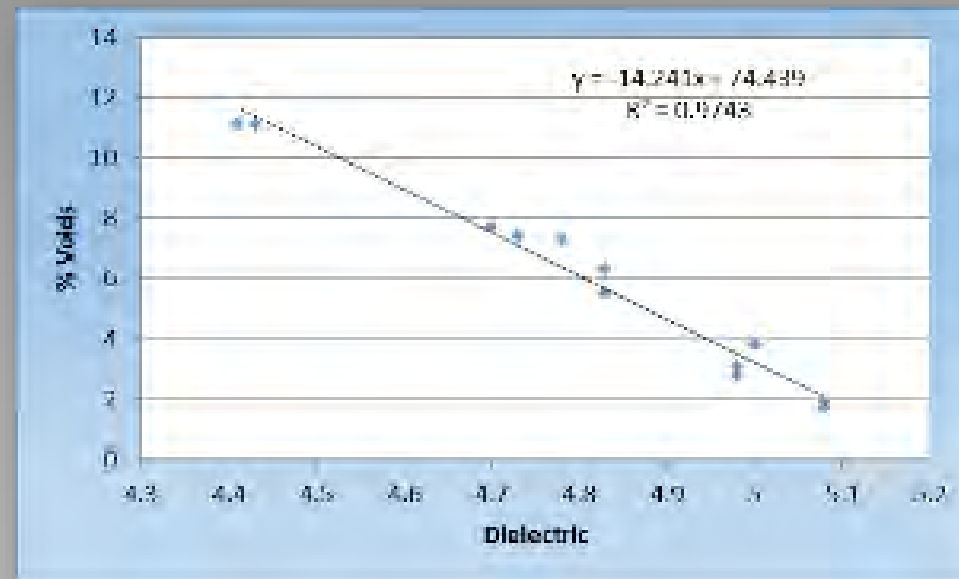


Calibration using Cores

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 of the PaveScan RDM 2.0 system. The screen is titled 'PaveScan RDM 2.0' and 'Warmup Complete'. It features a list of input fields for data entry, each with a corresponding label and a text 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 of the screen, there are two large orange buttons: 'Back' on the left and 'Collect' on the right.

Input Information

* Other Terms – Pills, Biscuits, Bulks



Calibration using Pucks

PaveScan RDM 2.0



4-Step Process



Calibration using Pucks

PaveScan RDM 2.0

Measurements **PaveScan RDM** Loading complete

File Name	Bulk Dielectric	Air Void %	Target Air Void %	Tested Side	Lab Thickness (mm)	
File	4.401	11.54	12	B	115.5	File Properties
File_001	4.401	11.54	12	B	115.5	File Properties
File_002	4.52	9.18	10	B	115.5	File Properties
File_003	4.583	9.18	10	B	115.3	File Properties
File_004	4.583	9.18	10	B	115.3	File Properties
File_005	4.69	7.9	8	B	116.4	File Properties
File_006	4.714	7.9	8	B	116.4	File Properties
File_007	4.892	5.01	6	B	114.8	File Properties
File_008	4.892	5.01	6	B	114.8	File Properties
File_009	4.934	3.63	4	B	114.9	File Properties
File_010	4.909	3.63	4	B	114.9	File Properties
File_011	4.992	2.84	2	B	115.1	File Properties
File_012	4.992	2.84	2	B	115.1	File Properties

Back Generate Mix Calibration

Results



System QA Procedures

PaveScan RDM 2.0

Procedures were developed to assure the accuracy of the sensors.

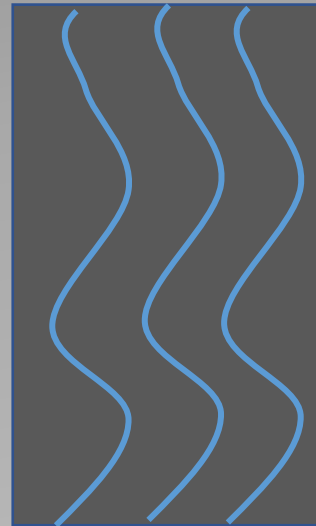
- HDPE Block
- Swerve Method
- Repeat Line Method

HDPE Block



Each Sensor, Dielectric = ~ 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 Define

Mat PWL Upper Limit (Dist.)

Mat PWL Lower Limit (Dist.)

Joint PWL Upper Limit (Dist.)

Joint PWL Lower Limit (Dist.)

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

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

Histogram Bin Interval (Dist.)

Histogram Maximum Value (Dist.)

Histogram Minimum Value (Dist.)

Back Save

User-selected upper and lower limits

Summary Statistics

Distance Range	Mat Statistic	Mat Status	Min. Lat Offset	Max. Lat Offset	Mat PWL	Joint PWL	Mat Median	Joint Median	Mat Std Dev	Joint Std Dev
Segment	726+00	726+00	12L	24L	0	30.89	0	4.89	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	01.84	0	4.93	0	0.14
Segment	741+00	742+00	12L	24L	0	01.54	0	4.33	0	0.14
Segment	757+07	752+00	24L	30L	12.3	0	4.7	0	0.16	0
Segment	772+00	735+00	24L	30L	0.84	0	4.74	0	0.17	0
Segment	770+00	735+00	24L	30L	20.36	0	3.8	0	0.16	0
Segment	754+00	735+00	24L	30L	14.59	0	4.78	0	0.14	0
Segment	778+00	789+00	24L	30L	0.0	0	6.71	0	0.17	0
Segment	726+00	737+00	24L	30L	26.07	0	4.81	0	0.2	0
Total	721+07	071+00	1.6	3.6	60.7	0.89	4.67	0.01	0.19	0.14

Back

Displayed Report



PWL Reports

PaveScan RDM 2.0

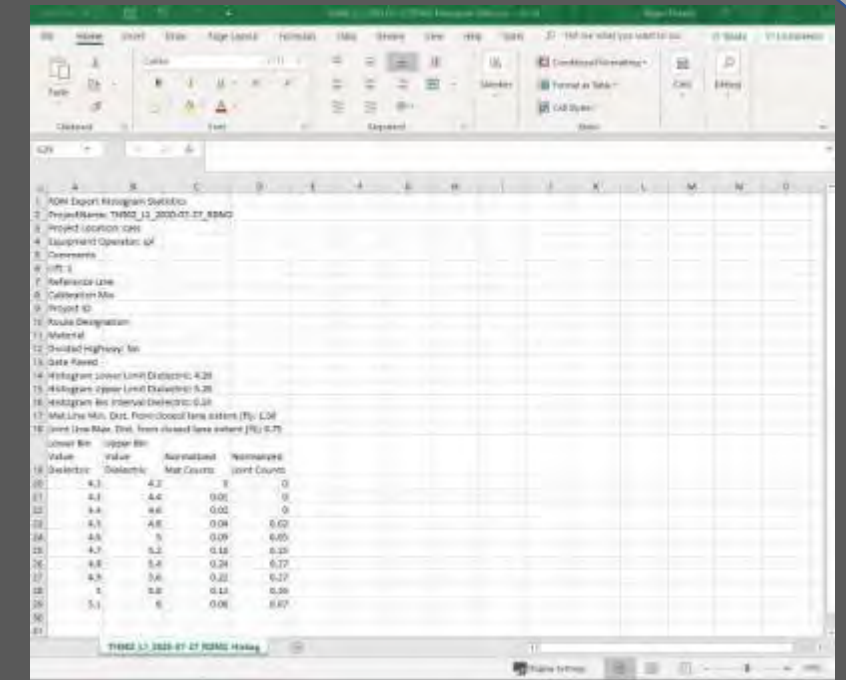
Exported PWL Reports (.csv format)

Start	End	Mat	Joint	Mean	Std Dev	Max	Min	Count
20	21	10100	10100	4.15	0.15	4.30	4.00	10
22	23	10200	10200	4.18	0.16	4.33	4.03	10
24	25	10300	10300	4.21	0.17	4.36	4.06	10
26	27	10400	10400	4.24	0.18	4.39	4.09	10
28	29	10500	10500	4.27	0.19	4.42	4.12	10
30	31	10600	10600	4.30	0.20	4.45	4.15	10
32	33	10700	10700	4.33	0.21	4.48	4.18	10
34	35	10800	10800	4.36	0.22	4.51	4.21	10
36	37	10900	10900	4.39	0.23	4.54	4.24	10
38	39	11000	11000	4.42	0.24	4.57	4.27	10
40	41	11100	11100	4.45	0.25	4.60	4.30	10
42	43	11200	11200	4.48	0.26	4.63	4.33	10
44	45	11300	11300	4.51	0.27	4.66	4.36	10
46	47	11400	11400	4.54	0.28	4.69	4.39	10
48	49	11500	11500	4.57	0.29	4.72	4.42	10
50	51	11600	11600	4.60	0.30	4.75	4.45	10
52	53	11700	11700	4.63	0.31	4.78	4.48	10
54	55	11800	11800	4.66	0.32	4.81	4.51	10
56	57	11900	11900	4.69	0.33	4.84	4.54	10
58	59	12000	12000	4.72	0.34	4.87	4.57	10
60	61	12100	12100	4.75	0.35	4.90	4.60	10
62	63	12200	12200	4.78	0.36	4.93	4.63	10
64	65	12300	12300	4.81	0.37	4.96	4.66	10
66	67	12400	12400	4.84	0.38	4.99	4.69	10
68	69	12500	12500	4.87	0.39	5.02	4.72	10
70	71	12600	12600	4.90	0.40	5.05	4.75	10
72	73	12700	12700	4.93	0.41	5.08	4.78	10
74	75	12800	12800	4.96	0.42	5.11	4.81	10
76	77	12900	12900	4.99	0.43	5.14	4.84	10
78	79	13000	13000	5.02	0.44	5.17	4.87	10
80	81	13100	13100	5.05	0.45	5.20	4.90	10

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

Start	End	Mat	Joint	Mean	Std Dev	Max	Min
20	81	10100	10100	4.15	0.15	4.30	4.00
22	23	10200	10200	4.18	0.16	4.33	4.03
24	25	10300	10300	4.21	0.17	4.36	4.06
26	27	10400	10400	4.24	0.18	4.39	4.09
28	29	10500	10500	4.27	0.19	4.42	4.12
30	31	10600	10600	4.30	0.20	4.45	4.15
32	33	10700	10700	4.33	0.21	4.48	4.18
34	35	10800	10800	4.36	0.22	4.51	4.21
36	37	10900	10900	4.39	0.23	4.54	4.24
38	39	11000	11000	4.42	0.24	4.57	4.27
40	41	11100	11100	4.45	0.25	4.60	4.30
42	43	11200	11200	4.48	0.26	4.63	4.33
44	45	11300	11300	4.51	0.27	4.66	4.36
46	47	11400	11400	4.54	0.28	4.69	4.39
48	49	11500	11500	4.57	0.29	4.72	4.42
50	51	11600	11600	4.60	0.30	4.75	4.45
52	53	11700	11700	4.63	0.31	4.78	4.48
54	55	11800	11800	4.66	0.32	4.81	4.51
56	57	11900	11900	4.69	0.33	4.84	4.54
58	59	12000	12000	4.72	0.34	4.87	4.57
60	61	12100	12100	4.75	0.35	4.90	4.60
62	63	12200	12200	4.78	0.36	4.93	4.63
64	65	12300	12300	4.81	0.37	4.96	4.66
66	67	12400	12400	4.84	0.38	4.99	4.69
68	69	12500	12500	4.87	0.39	5.02	4.72
70	71	12600	12600	4.90	0.40	5.05	4.75
72	73	12700	12700	4.93	0.41	5.08	4.78
74	75	12800	12800	4.96	0.42	5.11	4.81
76	77	12900	12900	4.99	0.43	5.14	4.84
78	79	13000	13000	5.02	0.44	5.17	4.87
80	81	13100	13100	5.05	0.45	5.20	4.90
82	83	13200	13200	5.08	0.46	5.23	4.93
84	85	13300	13300	5.11	0.47	5.26	4.96
86	87	13400	13400	5.14	0.48	5.29	4.99
88	89	13500	13500	5.17	0.49	5.32	5.02
90	91	13600	13600	5.20	0.50	5.35	5.05
92	93	13700	13700	5.23	0.51	5.38	5.08
94	95	13800	13800	5.26	0.52	5.41	5.11
96	97	13900	13900	5.29	0.53	5.44	5.14
98	99	14000	14000	5.32	0.54	5.47	5.17
100	101	14100	14100	5.35	0.55	5.50	5.20

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

User-selected criteria



Linear and Area Defects

PaveScan RDM 2.0

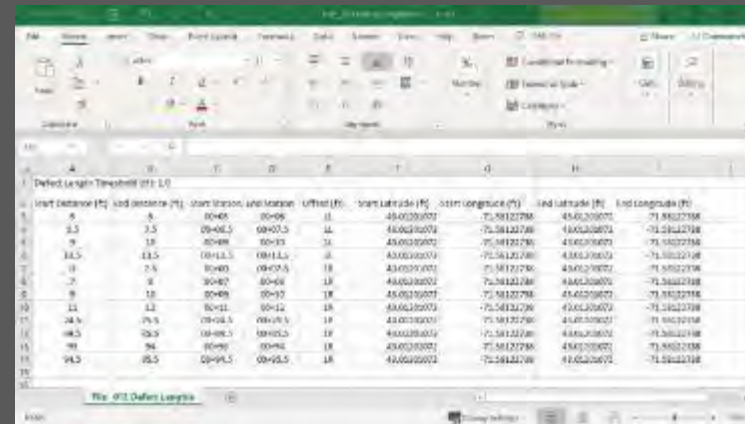
Exported Reports (.csv format)



Segment Summary

Defect Threshold	Compaction	Stations	Segment Length (ft)	# Defects	% Defective	Straddles adjacent segment
1200	32-06	180	1	1201	10.53	FALSE
1200	32-06	180	1	1201	10.53	FALSE

Segment Summary



Linear Defect File

Start Distance (ft)	End Distance (ft)	Start Station	End Station	Offset (ft)	Start Latitude (N)	Start Longitude (W)	End Latitude (N)	End Longitude (W)
0	0	00+00	00+00	11	48.0020001	71.5812778	48.0020001	71.5812778
3.5	3.5	00+00.5	00+00.5	11	48.0020001	71.5812778	48.0020001	71.5812778
7	7	00+01	00+01	11	48.0020001	71.5812778	48.0020001	71.5812778
10.5	10.5	00+01.5	00+01.5	11	48.0020001	71.5812778	48.0020001	71.5812778
14	14	00+02	00+02	11	48.0020001	71.5812778	48.0020001	71.5812778
17.5	17.5	00+02.5	00+02.5	11	48.0020001	71.5812778	48.0020001	71.5812778
21	21	00+03	00+03	11	48.0020001	71.5812778	48.0020001	71.5812778
24.5	24.5	00+03.5	00+03.5	11	48.0020001	71.5812778	48.0020001	71.5812778
28	28	00+04	00+04	11	48.0020001	71.5812778	48.0020001	71.5812778
31.5	31.5	00+04.5	00+04.5	11	48.0020001	71.5812778	48.0020001	71.5812778
35	35	00+05	00+05	11	48.0020001	71.5812778	48.0020001	71.5812778

Linear Defect File



KML File (display using Google Earth)



Deployment Options

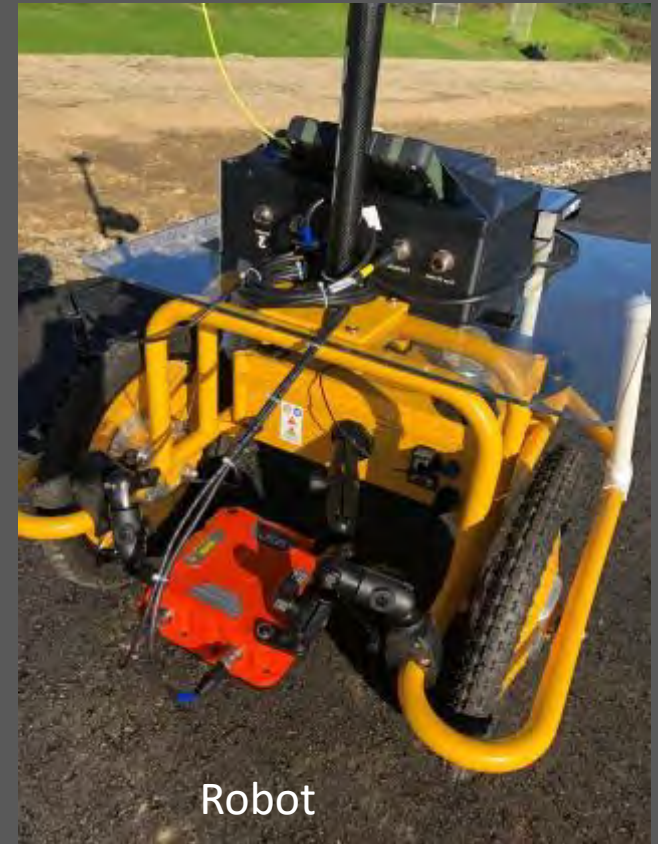
PaveScan RDM 2.0



Vehicle (Van, Golf Cart...)



Segway

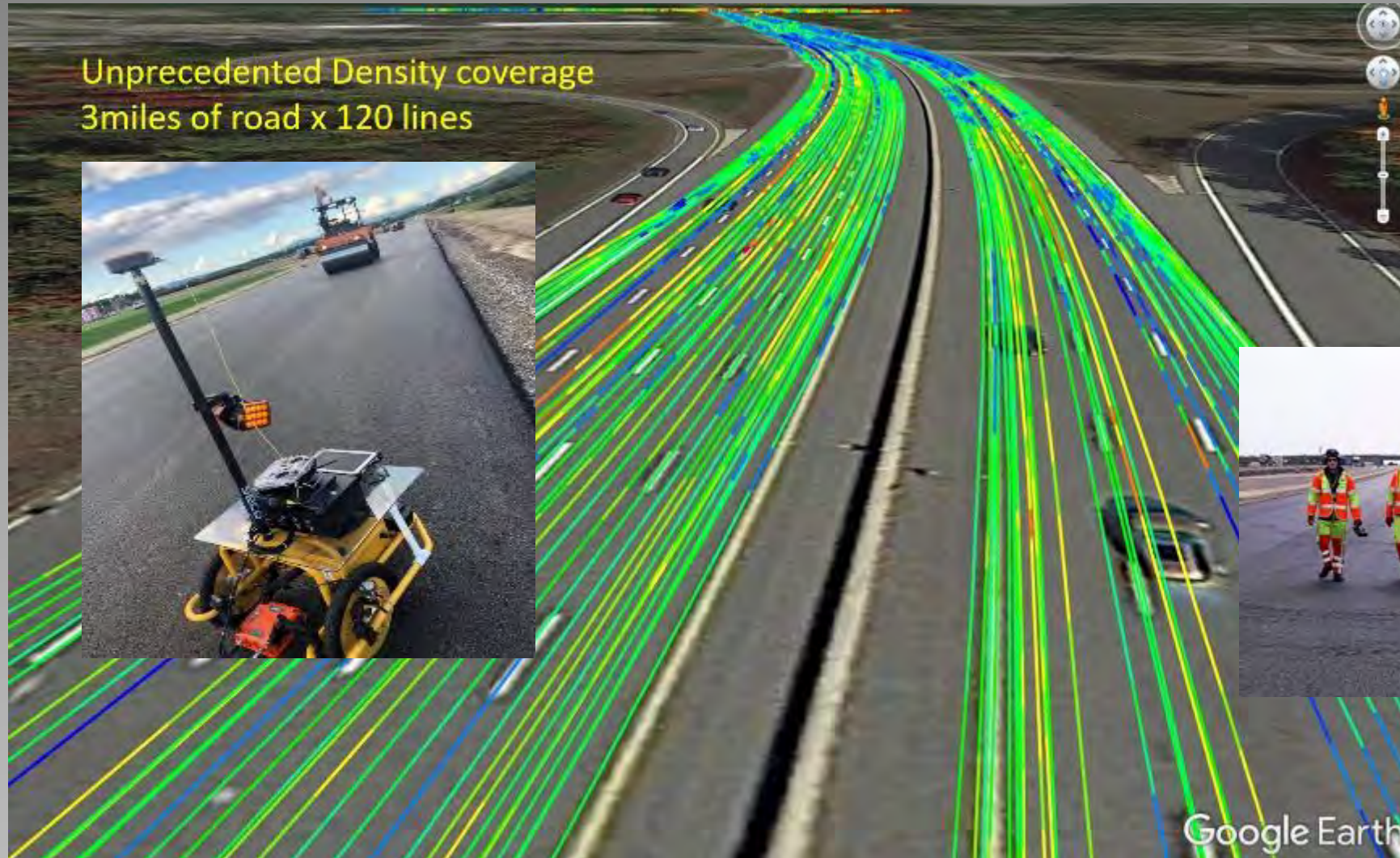


Robot



Deployment Options

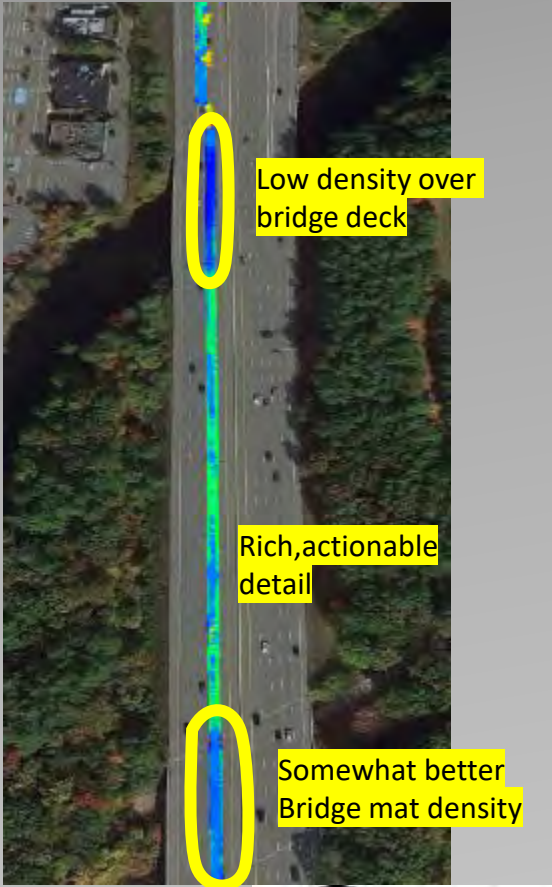
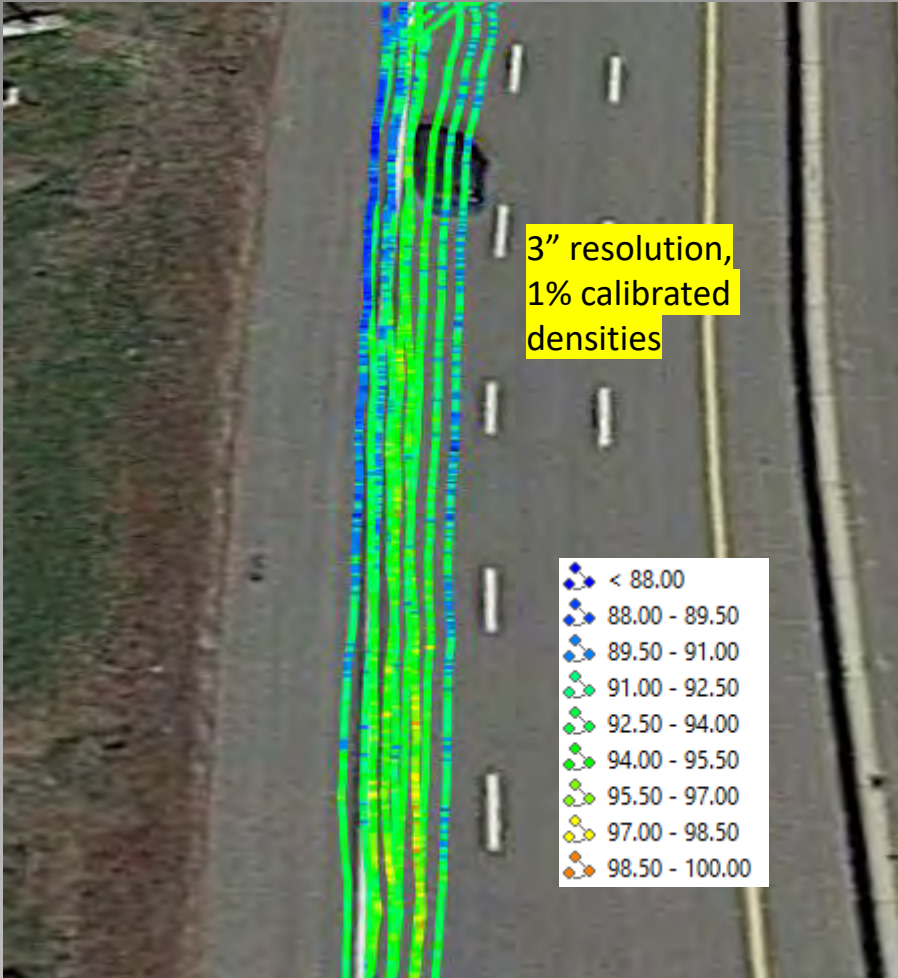
PaveScan RDM 2.0



KML file (Google Earth)

PaveScan RDM 2.0

Examples

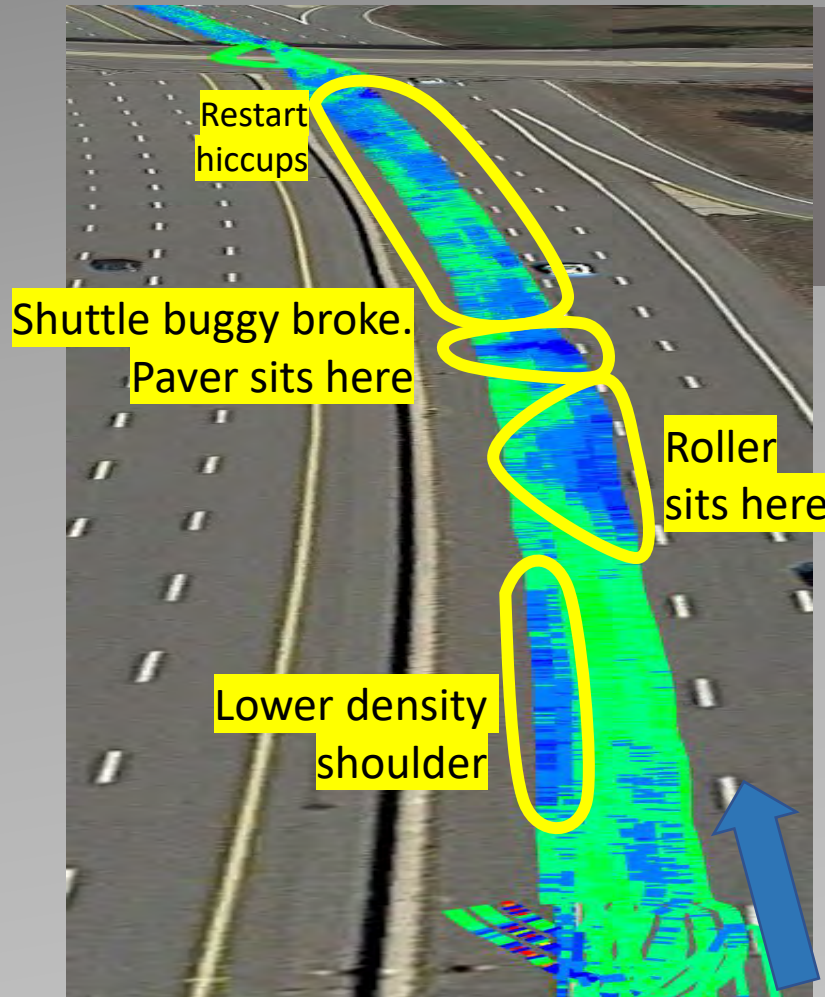


KML file (Google Earth)

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



KML file (Google Earth)

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Examples

Correlation:
Lower density vs IR Map



Questions

PaveScan RDM 2.0

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Thank You!!

