Illinois Center for Transportation
University of Illinois at Urbana-Champaign

ILLINOIS

Continuous Density Measurements of Flexible Pavement during Construction

12/06/2023

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Illinois Bituminous Paving Conference

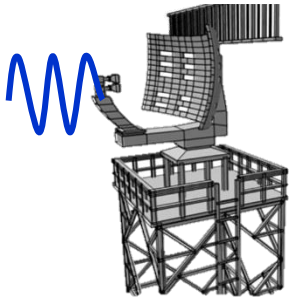
Acknowledgement

- FHWA Accelerating Market Readiness Program: Jeffery Zaharewicz and Ryan Buck
- IDOT: LaDonna Rowden and John Senger
- Gallagher Asphalt (Brian Gallagher and Steve Rubio) and Open Roads (Jeff Kern and John Miller)
- Research engineers: Greg Renshaw, Mohsen Motlagh and Uthman Mohammad Ali
- ICT students: Qingqing Cao, Amir Ibrahim, Zehui Zhu, Javier Garcia Mainieri, Mohammad Fakhreddine, Egemen Okte, Aravind Ramakrishnan, Gafar Sulaiman, Aditya Singh and Akash Bajaj

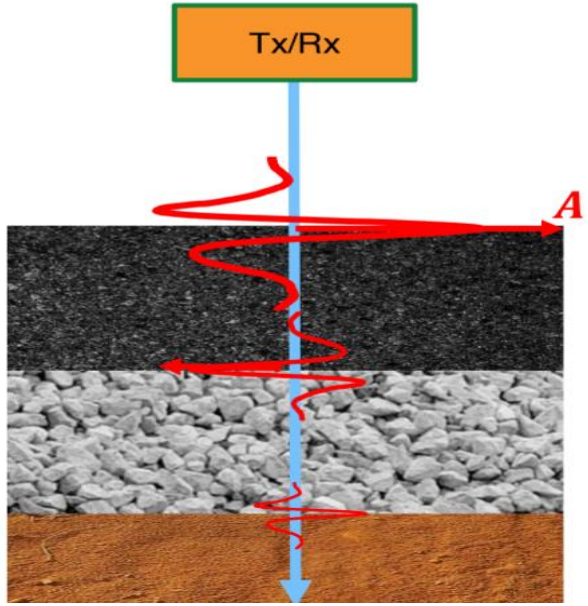
Outline

I Background

Ground Penetrating Radar (GPR)



Detection depends on contrast in material dielectric properties



Detects ground objects	EM waves can penetrate the ground	Special kind of radar

Mix Design Properties

- G_{mm}
- G_{se}
- P_b
- Aggregate Type

ALL

Model

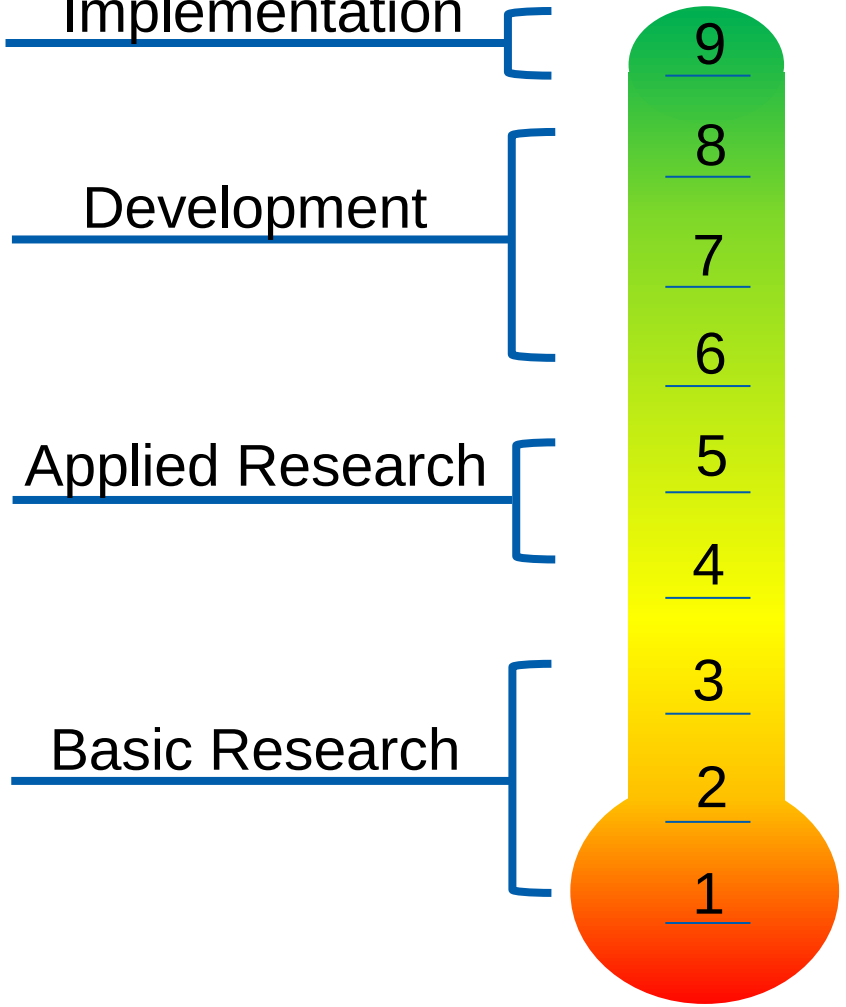
G_{mb}

Motivation

- **GPR overcomes several limitations of other asphalt concrete (AC) density prediction methods**

Continuous	Large coverage area	Rapid/efficient
Safe use	Temperature independent	Flexible

- **This technology is at TRL 6 and advancing…**



Technology Readiness Level – Highway (FHWA)

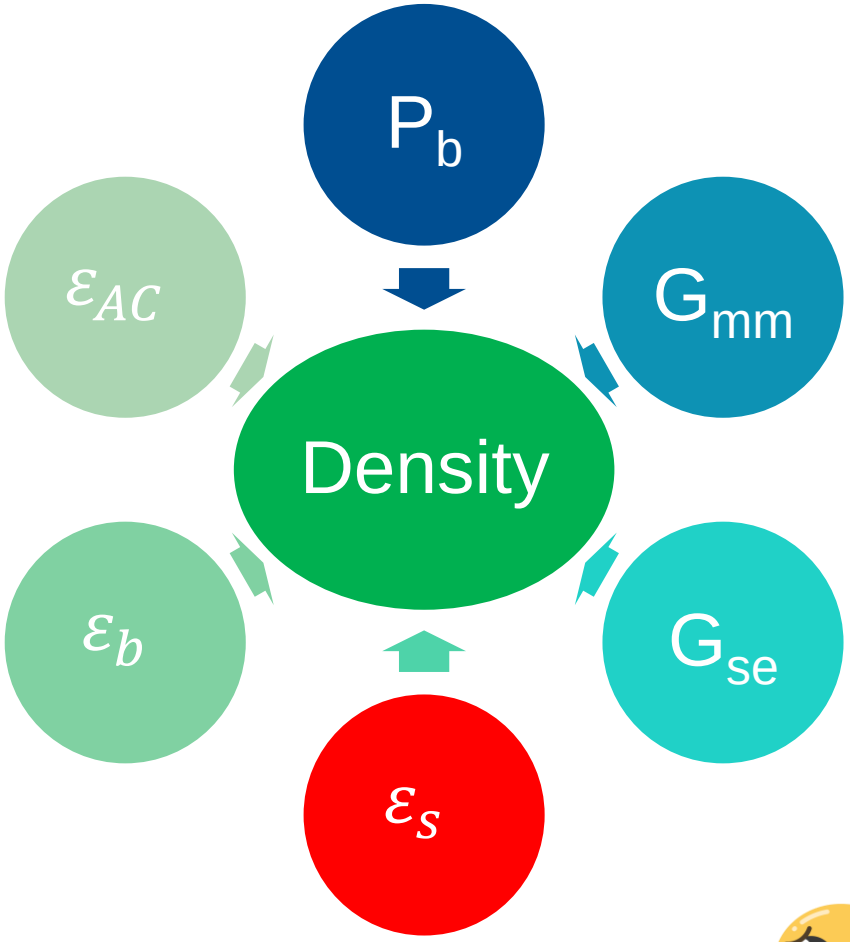
II Project Overview

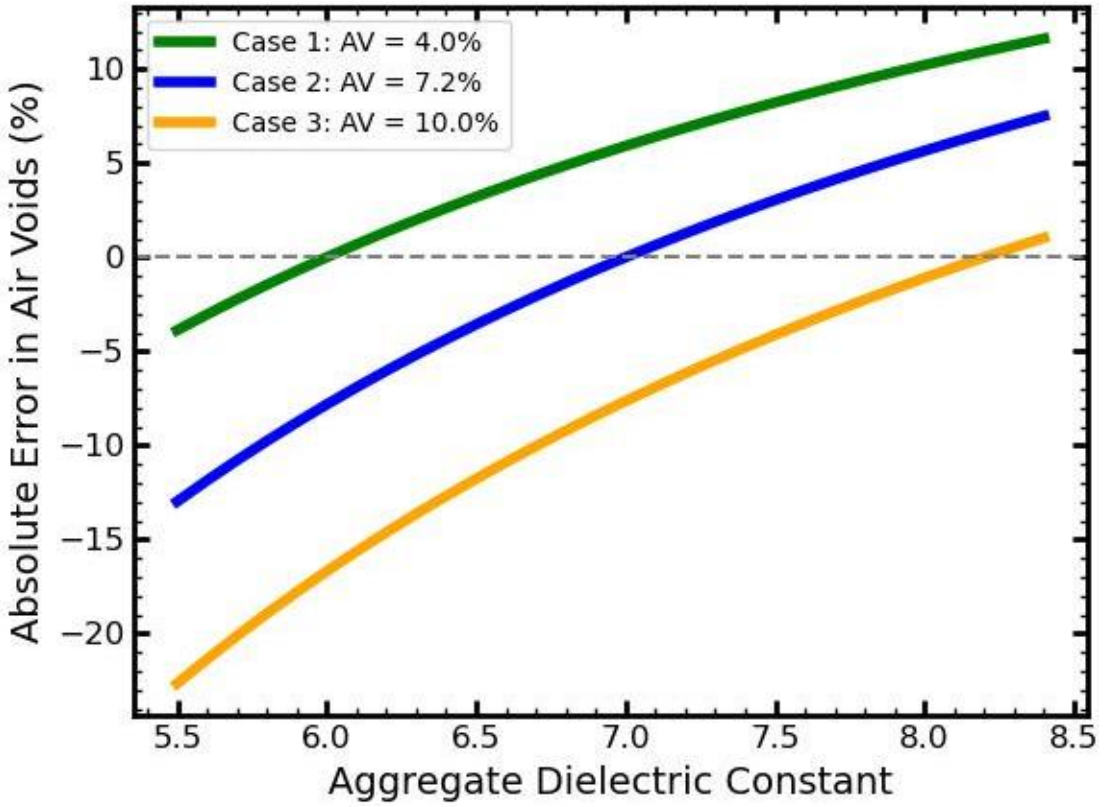
Theory
Models/Algorithms
(2010-now)

Software
Program
(2020-now)

Application
on a compactor!
(2021-now)

III Aggregate Database

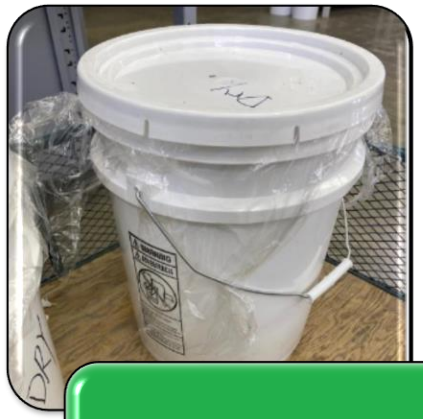




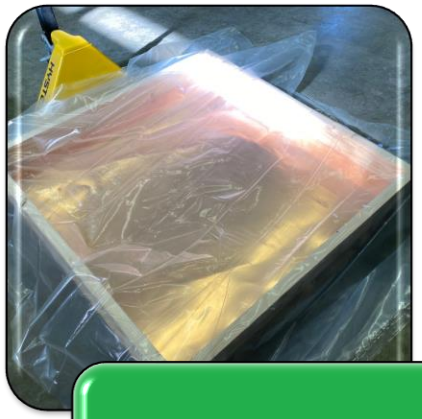
ε_s **is usually back-calculated from cores**

ALL model is sensitive to ε_s (Aggregates are 85% of mix!)

Dielectric Constant Measurement



Drying and sealing



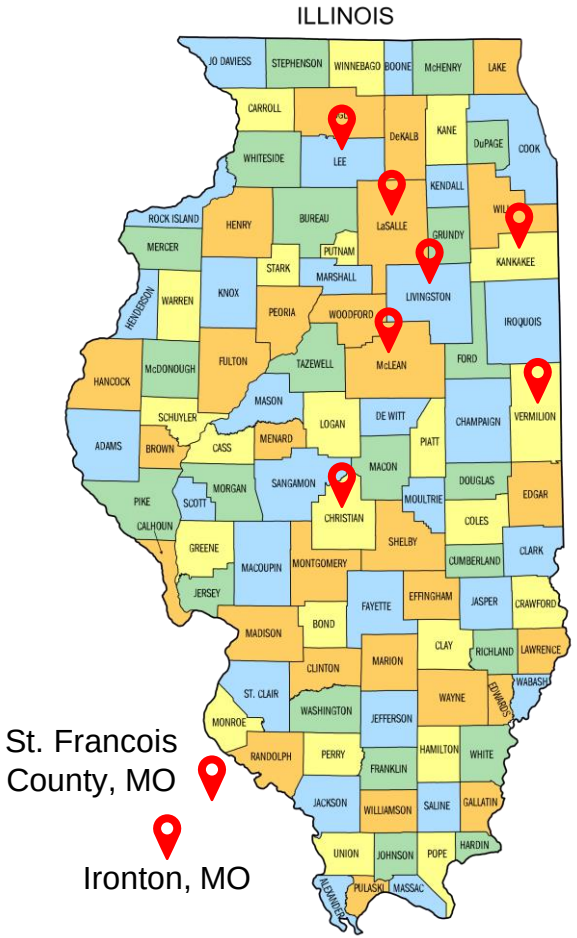
Frame preparation

Weighing aggregates

Testing

Results

- **Aggregates commonly used in Illinois: Limestone, Dolomite, Traprock, Granite and Crushed Gravel**



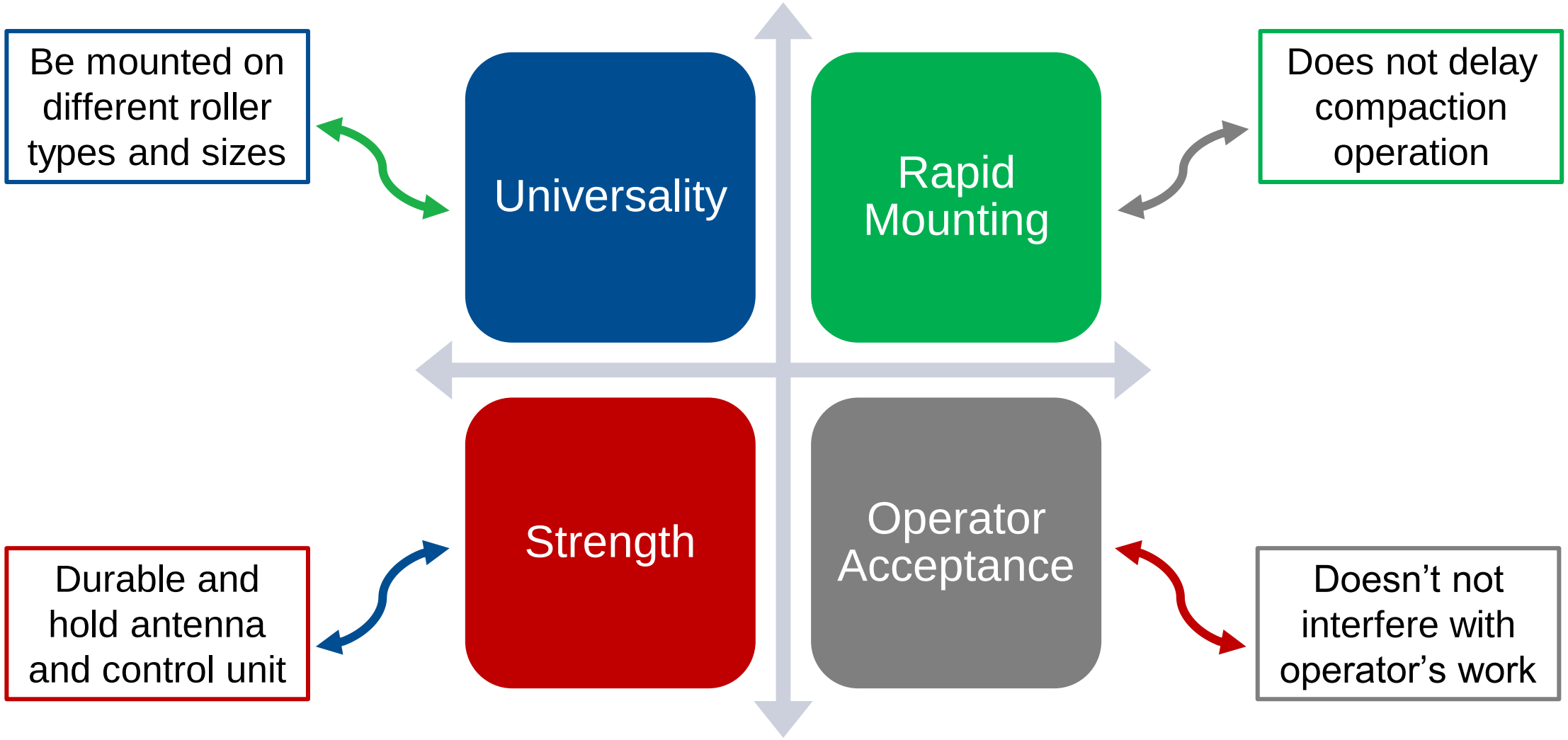
Aggregate Type	Quarry Location	Specific Gravity	Dielectric Constant	Avg ε	CoV ε
Dolomite	Troy Grove, IL	2.632	7.40-7.57	**7.35**	0.03
Dolomite	Amboy, IL	2.618	7.02-7.20		
Dolomite	Kankakee, IL	2.611	7.37-7.56		
Limestone	Pana, IL	2.600	8.10	**8.06**	0.04
Limestone	Fairmount, IL	2.590	8.25-8.47		
Limestone	McDowel, IL	2.582	7.64-7.82		
Trap Rock	Ironton, MO	2.635	6.60	**6.25**	0.06
Trap Rock	Farmington, MO	2.593	5.80-5.99		
Granite	Farmington, MO	2.587	5.96-6.14	**6.05**	0.02
Crushed Gravel	Heyworth, IL	2.605	6.50-6.67	**6.59**	0.02

Validation

- **Laboratory and field data for validation**

Data Source	ALL Model Inputs					Predicted	Truth
	P_b (%)	G_{mm}	G_{se}	ε_s	ε_{AC}	AV (%)	AV (%)
Lab slab	6.1	2.497	2.750	8.05	4.85	16.7	16.2
Field Data	5.1	2.542	2.760	8.05	6.25	7.8	7-7.5

IV Hardware Goals



Prototype Evolvement

Trial 1: July 2021

Trial 2: October 2021

Trial 3: June 2022

Mount Evaluation

- Doesn’t affect roller
- Versatile (adjustable to any roller)
- Stable and durable
- Operator approved
- Current mounting time exceeds an hour
- Removal time is 20mins

Field Projects

Residential road, Bourbonnais, IL

June 30th, 2022

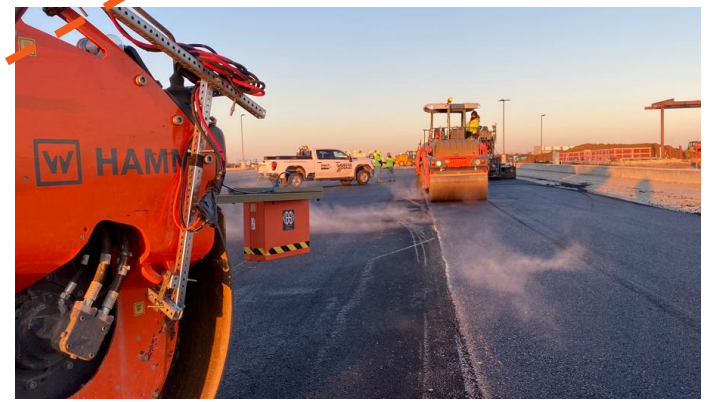
Harlem Ave, Chicago, IL

August 5th, 2022

Home Depot Parking, Joliet, IL

September 27th, 2022

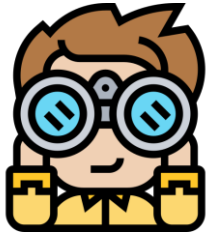
Road Ranger Station, Bourbonnais, IL



October 30th, 2023

Final Design – SMA Sections

Lower antenna height
Shorter beams
No vision obstruction
Monitor mount



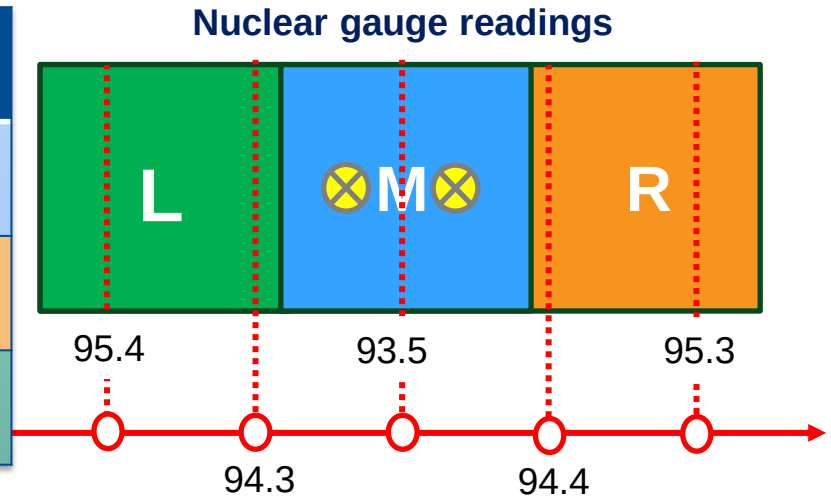
Lighter design
Faster mounting time
Tighter connections
On-board copper plate

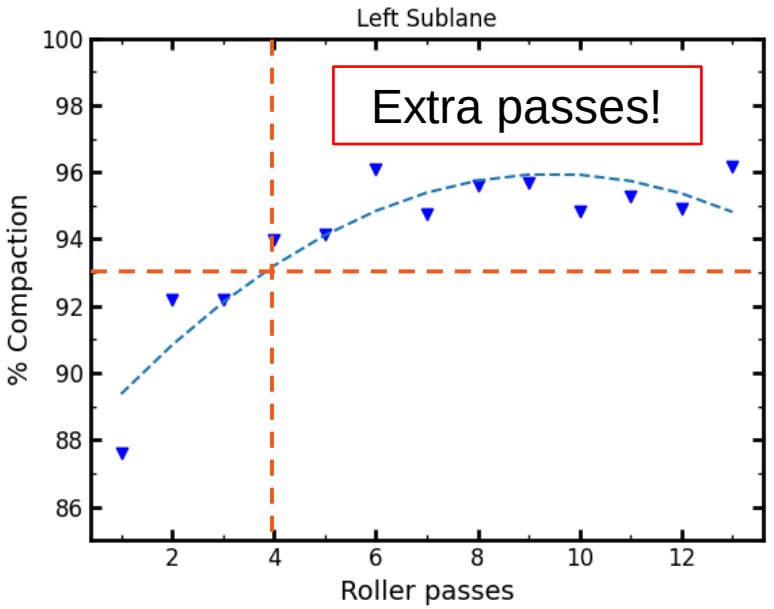
An IDOT project using local aggregates for SMA
- Six instrumented test sections of SMA with different aggregates
- GPR readings were collected with every pass during compaction

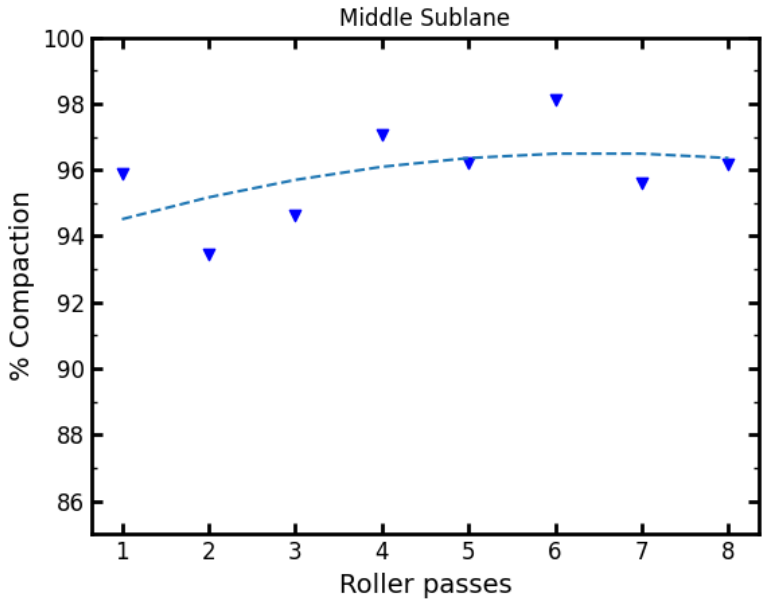
Example - Section B

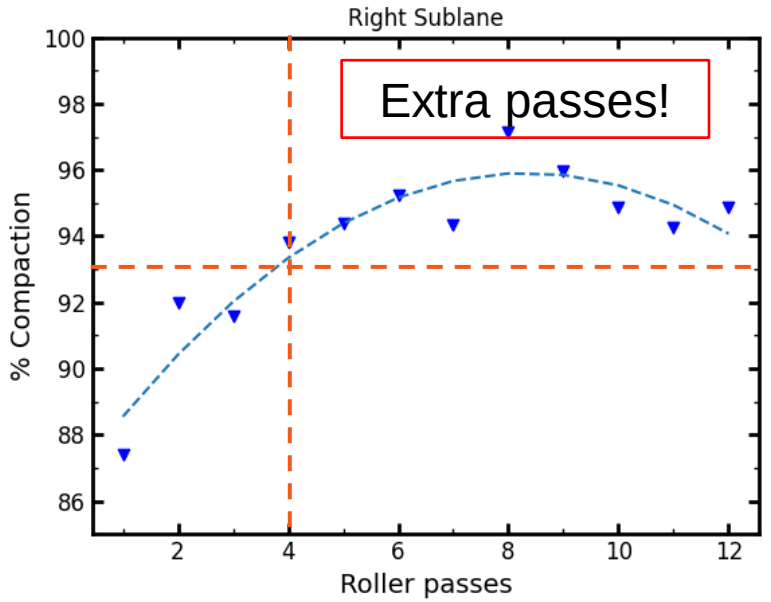
- **Trap rock** aggregate dielectric constant used from **database**
- Environmental and cost benefits when avoiding **over-compaction**
- Two middle sub-lane cores with both densities at **95.9%** ⊗

Method	Final %density
GPR	95.8
Core	95.9
Nuclear gauge	94.6





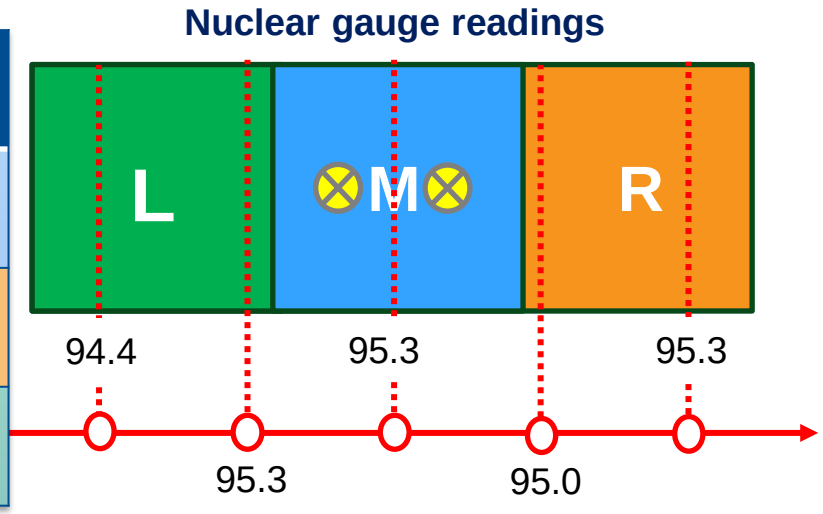


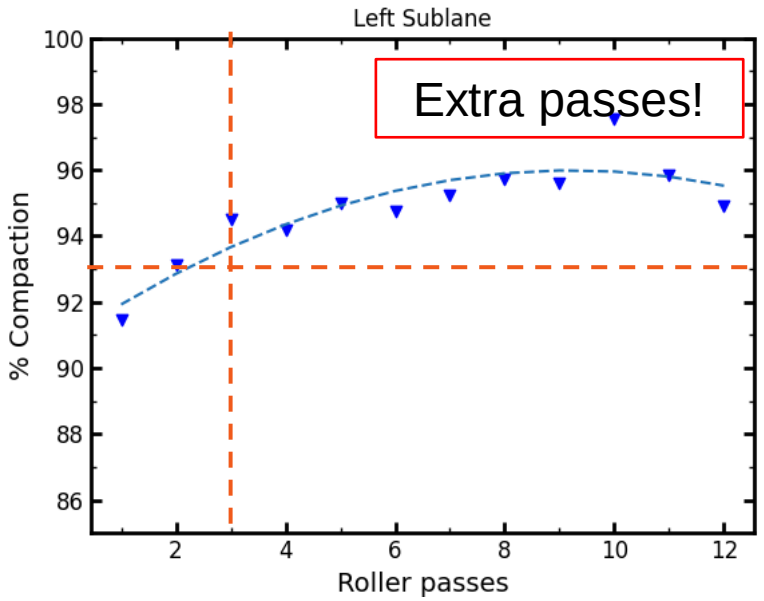


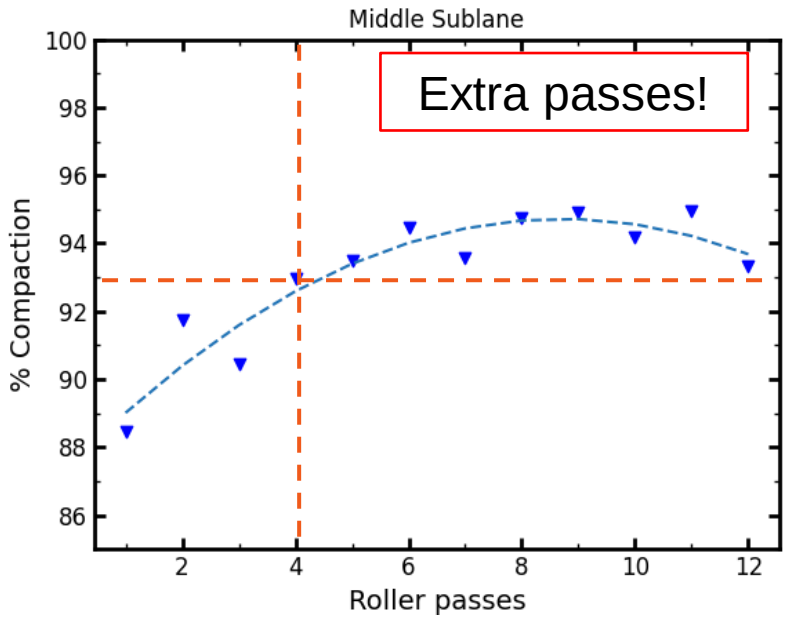
Example - Section E

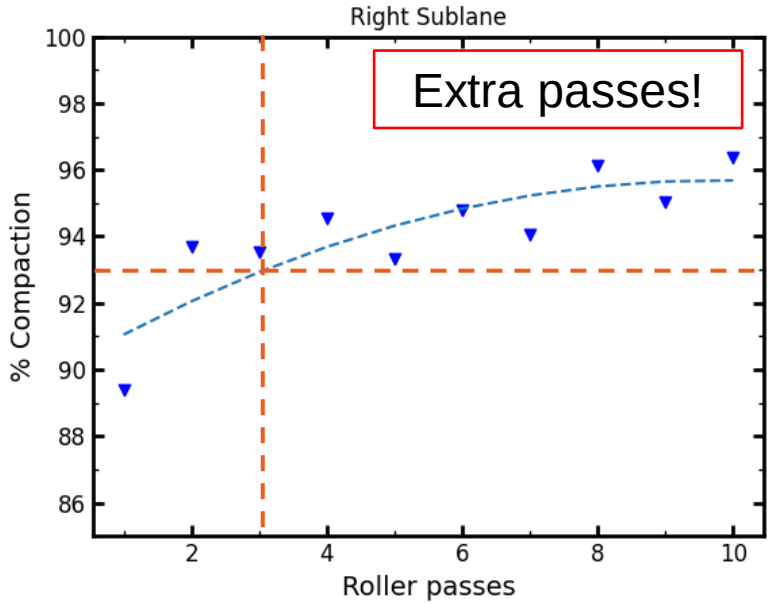
- **Dolomite** aggregate dielectric constant used from **database**
- Two middle sub-lane cores with densities **95.7% and 93.4%**
- Trap rock SMA achieved **higher** density than Dolomite SMA for similar number of passes

Method	Final %density
GPR	94.7
Core	94.6
Nuclear gauge	95.1



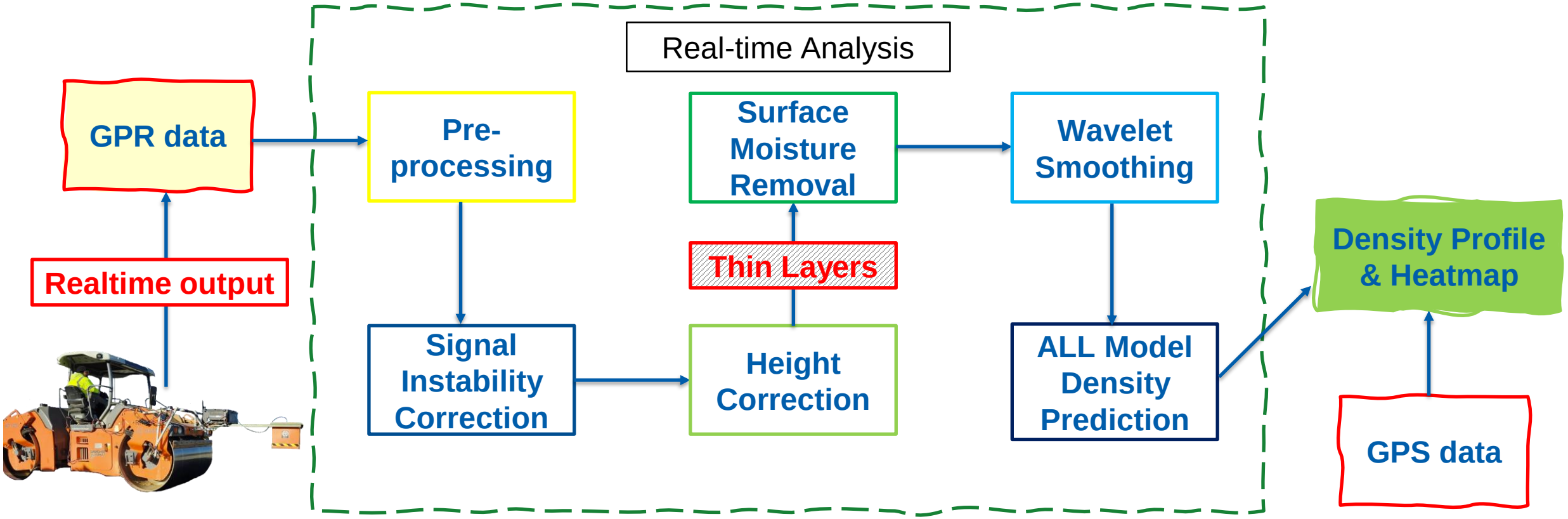






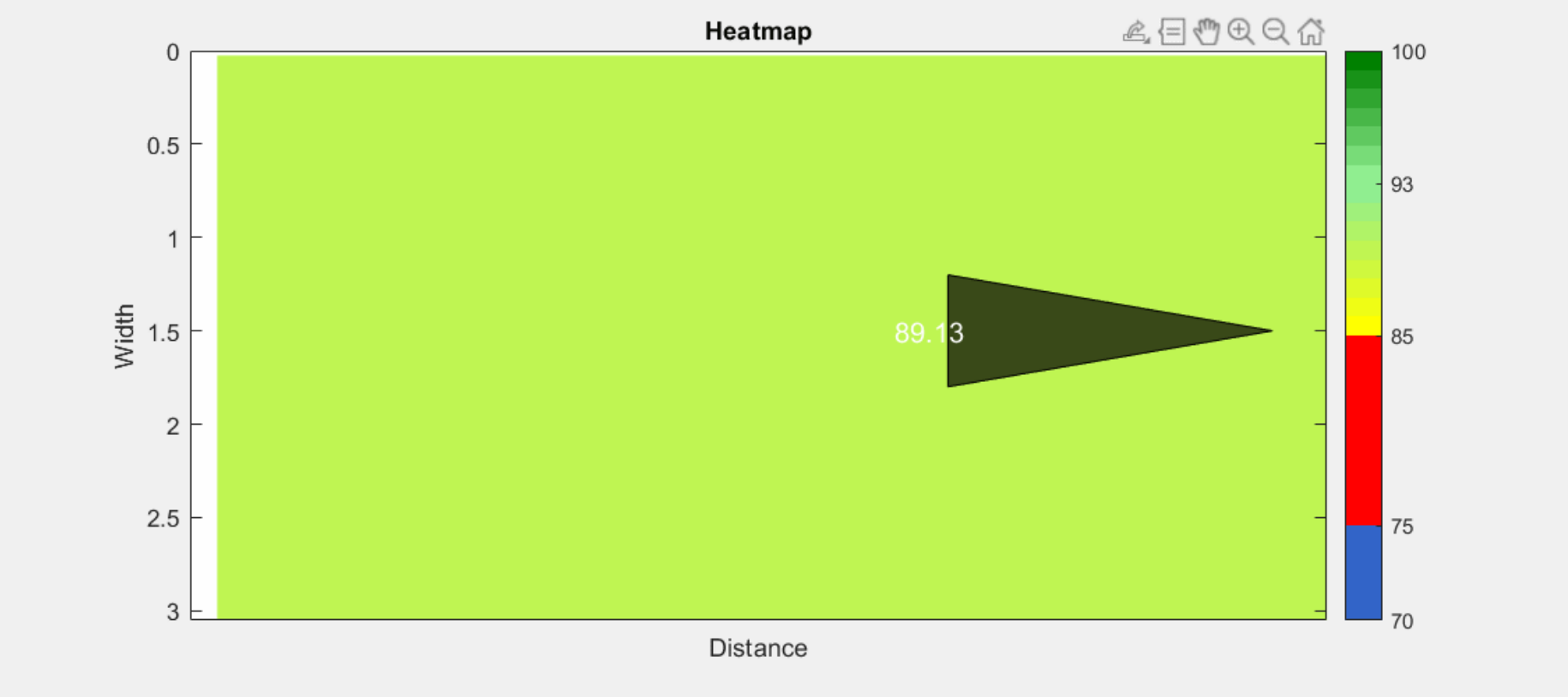
V Tool Development

- New tool is being developed (GPR-Analytics)
- The tool has an "HMA compaction monitoring" mode
- Thin layers algorithm for thin overlays (<1.2-in-thick) could be added



Heatmap Example

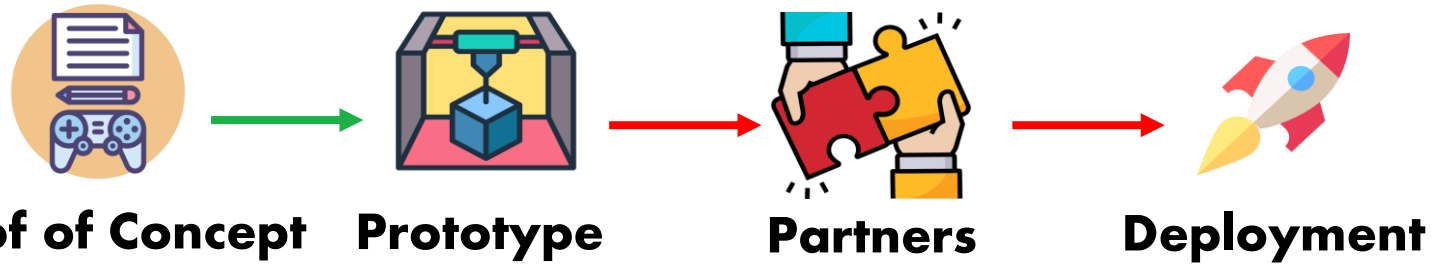
- Two passes are shown in this video with the arrow following the roller
- Density is reported to operator using the color scale on the right



VI Summary

- An Illinois validated aggregate dielectric constant database is being established (we provided the approach to FHWA)
- A versatile and durable GPR mount prototype was developed (operator accepted)
- An automated user-friendly tool is developed for density prediction
- Mount and tool were tested on various construction projects around Illinois

VII Next Steps



- Aggregate dielectric database: Expand and relate to chemical composition
- Hardware: Enhance robustness and mounting time
- Software: Faster processing speed and better interface design
- Technology commercialization and marketing are underway
- Explore other automation options

Contractor Feedback

- **Question: What do you think of this technology?**

Operator Feedback

- **Question: As an operator, do you like it?**

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THANK YOU

Any Questions?

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