



Pavement Evaluation 2019



September 17-20, 2019  
Roanoke, Virginia

# Calibration, Certification, and Verification of Transverse Pavement Profile Measurements

By

Craig Altmann & John Ferris

Vehicle Terrain Performance Laboratory  
Virginia Tech

# Today's Discussion

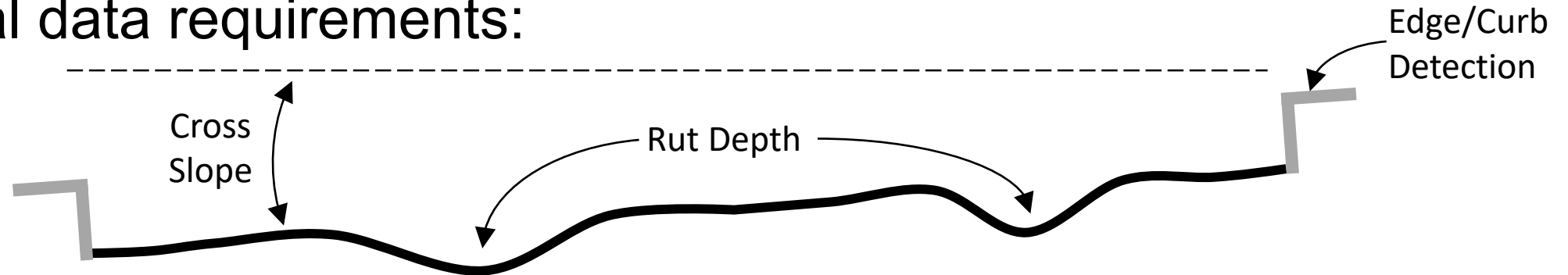
- Project Objectives and Background
- Work to Date
- Overview of Standards
- Explanation of Ground Reference Data and Analysis

# Objectives for Transverse Pavement Profile

- Determine precision and accuracy of highway speed transverse profile measurements
- Evaluate if the transverse pavement profiler measurements satisfy the accuracy and precision requirements
- Project Oversight Panel:
  - Weigel, ND
  - Andrews, former MD
  - Coplantz, OR
  - Miller, KS
  - Luhr, former WS
  - Li, TX
  - Mergenmeier, FHWA

# Project Background

- Final data requirements:



- Final Requirement Statement

Accuracy and Precision (mm)					
	Lower Bounds (mm)		Bias	Upper Bounds (mm)	
	90% (5%)	50% (25%)		50% (75%)	90% (95%)
Rut Depth Error	-2.5	-1.0	NA	1.0	2.5
Cross Slope Error (%)	-0.4	-0.15	NA	0.15	0.40
Edge/Curb Transverse Location Error	-50	-25	NA	25	50
Edge/Curb Vertical Magnitude Error	-2.5	-1.0	NA	1.0	2.5

# Work to Date

- Two Equipment Rodeos
  - April 2018
  - May 2019
- Five Proposed AASHTO Standards
  - Static Performance
  - Body Motion Cancelation
  - Navigation Drift
  - Highway Performance
  - Acceptance of Ground Reference Equipment

# Layers of Assessment

Requirements Definition

Process Flow

Reporting/Decision Analysis

Data Interpretation  
(e.g. quarter-car simulation)

Data Analysis (e.g. filtering, smoothing, outlier removal)

Data Acquisition  
(e.g. mapping and location sensor data)

Sensor Requirements (e.g. mapping sensor specifications)

D

C

B

A

Data Requirement Calculations:  
- Rut depth  
- Cross-slope  
- Edge location/height

Signal Processing:  
- Filtering  
- Lateral Shift  
- Outlier Removal

Test Conditions:  
- Calibration surfaces  
- Excitation  
- Speed

Sensor/System Specifications:  
- Transverse Resolution  
- Transverse Width

Data Requirement Assessment:  
- Accuracy & Precision

Gridded Data Assessment:  
- Edited regularly spaced data

Point Cloud Assessment:  
- Unfiltered/unedited data

Verification Tests:  
- Ensure system specifications are met

# Developed Certification Tests

## **Static performance**

Evaluate the accuracy and precision of the measurement sensors using traceable surfaces (straight edge and gauge blocks)

## **Body motion cancelation**

Evaluate the capability of the transverse pavement profiler to remove movement of the vehicle body due to primary ride and roll excitations

## **Navigation drift mitigation**

Evaluate the magnitude of drift present in the reported global position of a stationary object when repeat passes are made over the object

## **Typical highway performance**

Evaluate the accuracy and precision of the complete transverse pavement profiler during typical highway operations

# Static Performance

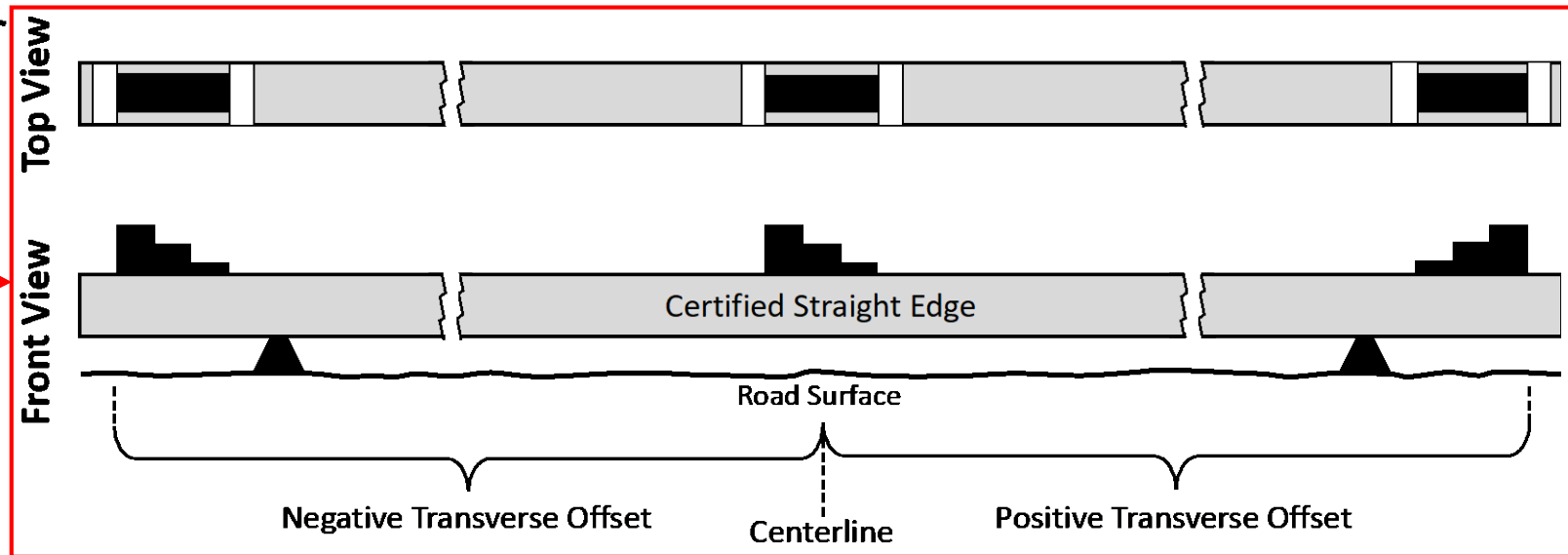
**Straight Edge Below Road Surface**

**Straight Edge Above Road Surface**

Measurement Sensor

Measurement Sensor

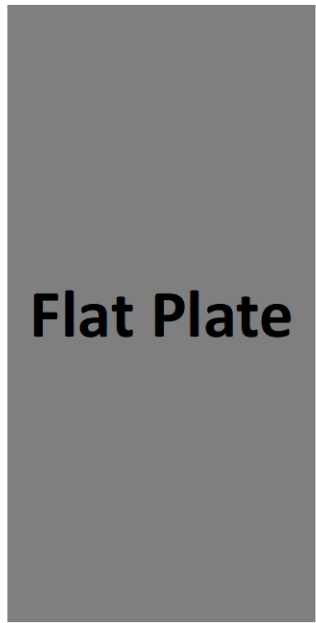
Output Test Statistics
Transverse Measurement Resolution
Transverse Measurement Error
Vertical Measurement Resolution
Vertical Measurement Error
Total Transverse Width
Straightness Error





# Body Motion Cancelation

Output Test Statistics
Vehicle Body Motion Error
Vertical Measurement Spacing



Flat Plate

Used for edge/curb detection

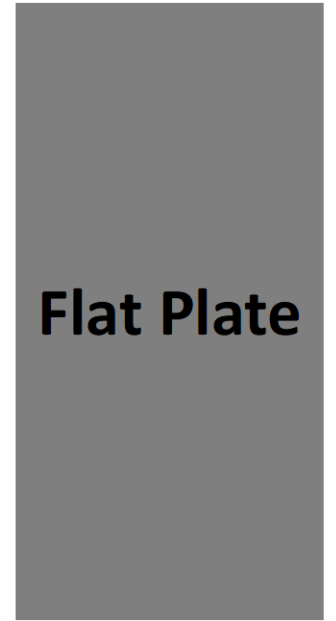
Excitation Board



Flat Plate

Used for rut depth and cross slope

Excitation Board



Flat Plate

Used for edge/curb detection

Offset for roll

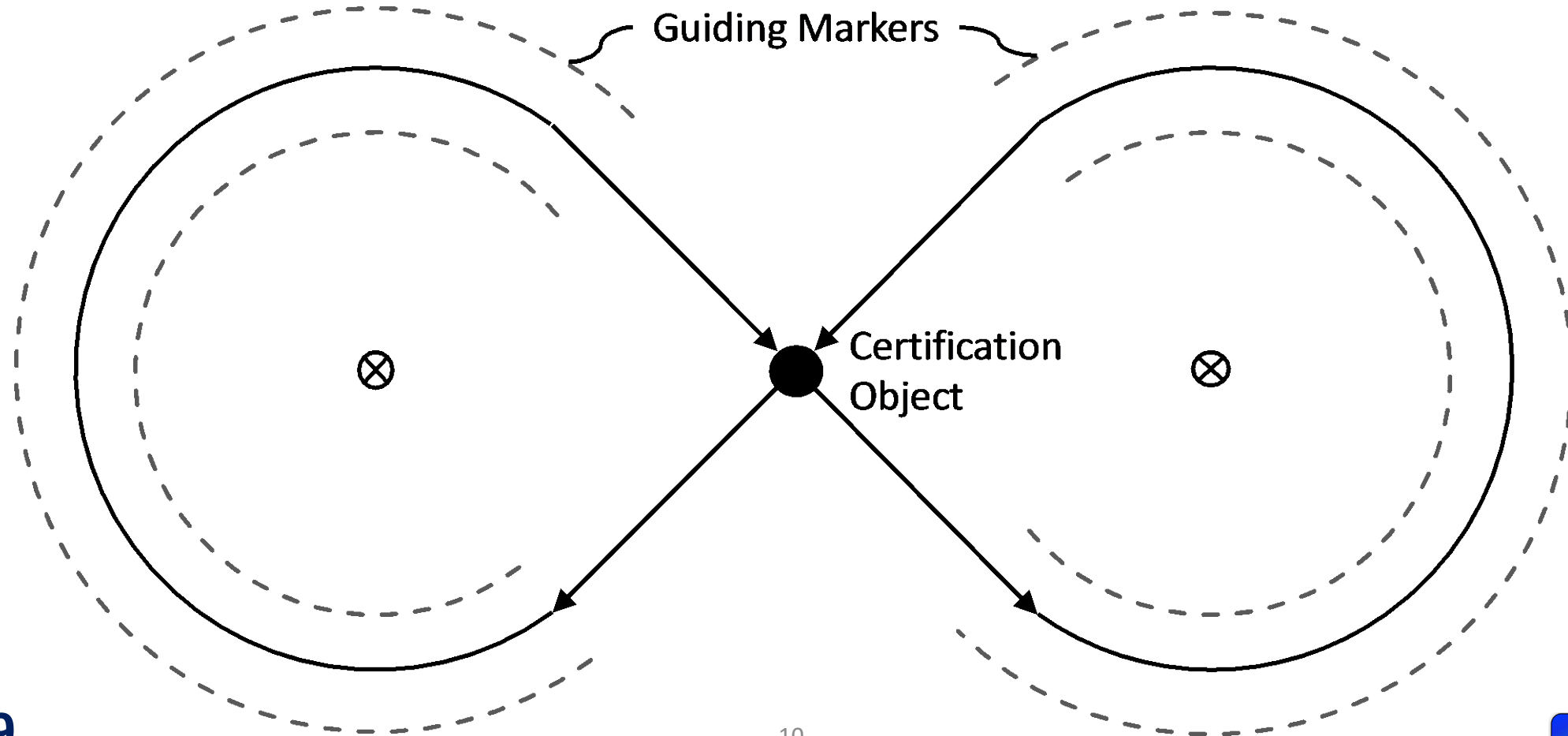
# Navigation Drift

## Output Test Statistics

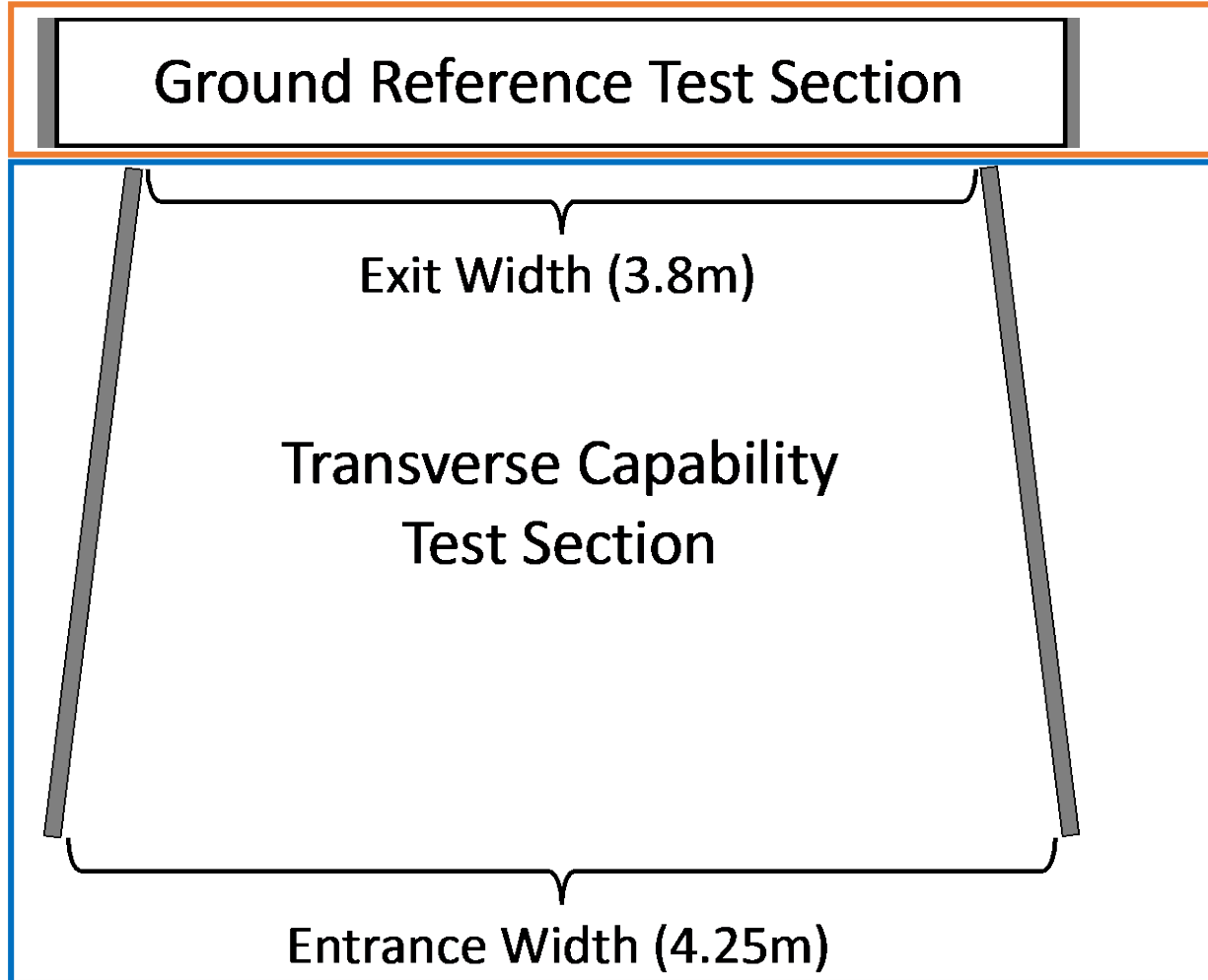
Easting Position Error

Northing Position Error

Elevation Repeatability



# Highway Performance



## Output Test Statistics (Ground Reference Test Section)

Point Cloud Vertical Error

Gridded Data Vertical Error

Cross Slope Error

Rut Depth Error

Edge/Curb Transverse Location Error

Edge/Curb Vertical Magnitude Error

## Output Test Statistics (Transverse Capability Test Section)

Transverse Measurement Spacing

Longitudinal Measurement Spacing

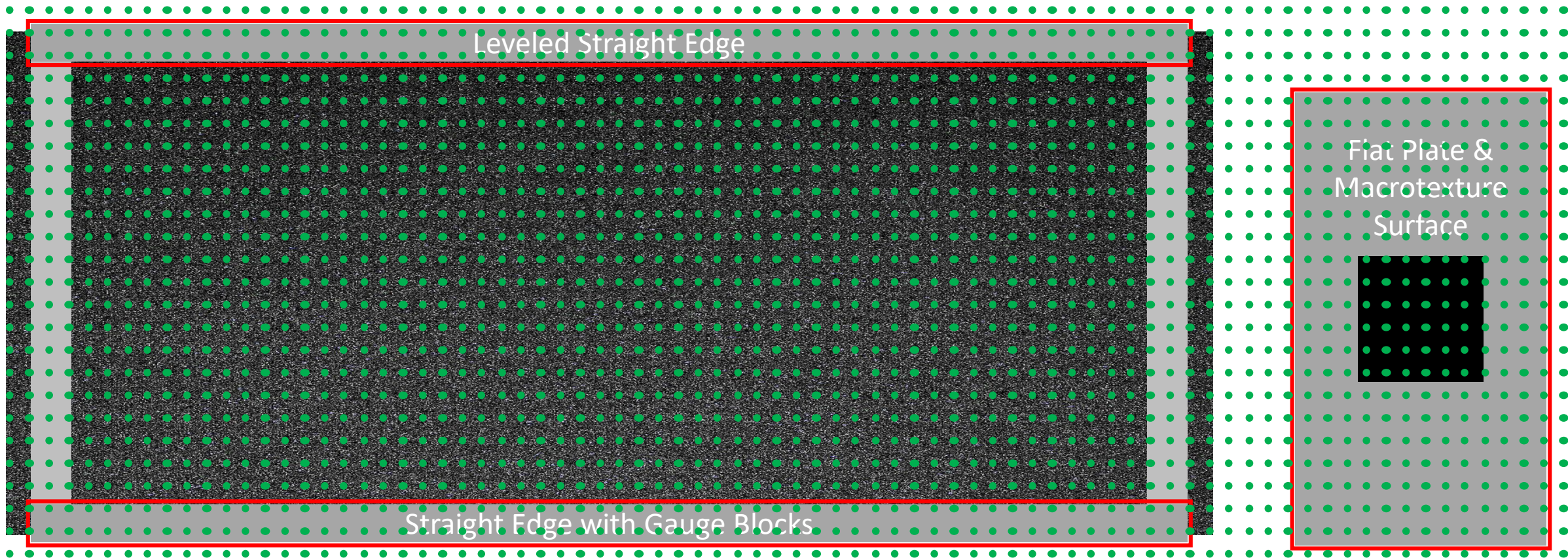
Effective Transverse Width

# Ground Reference

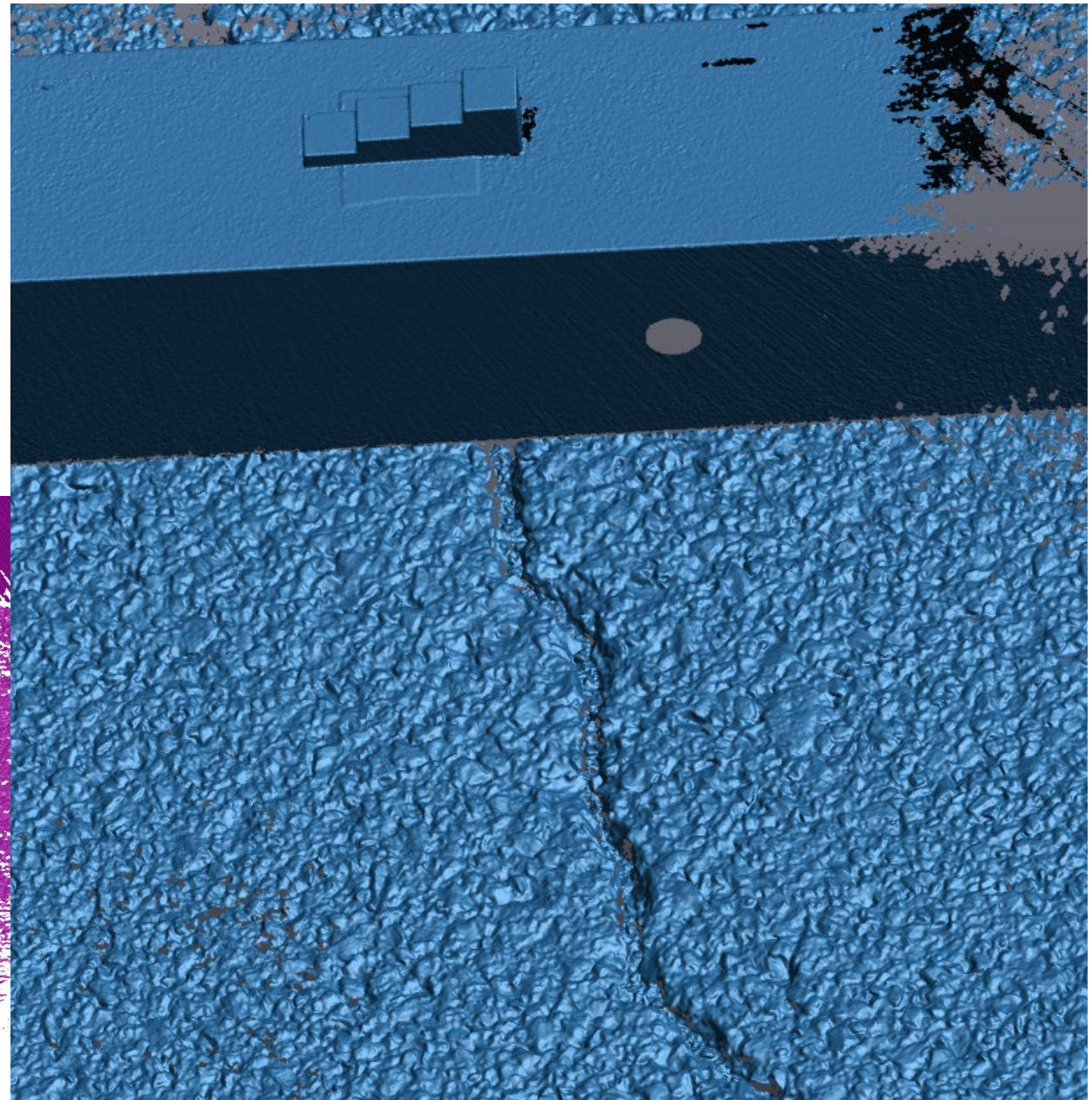
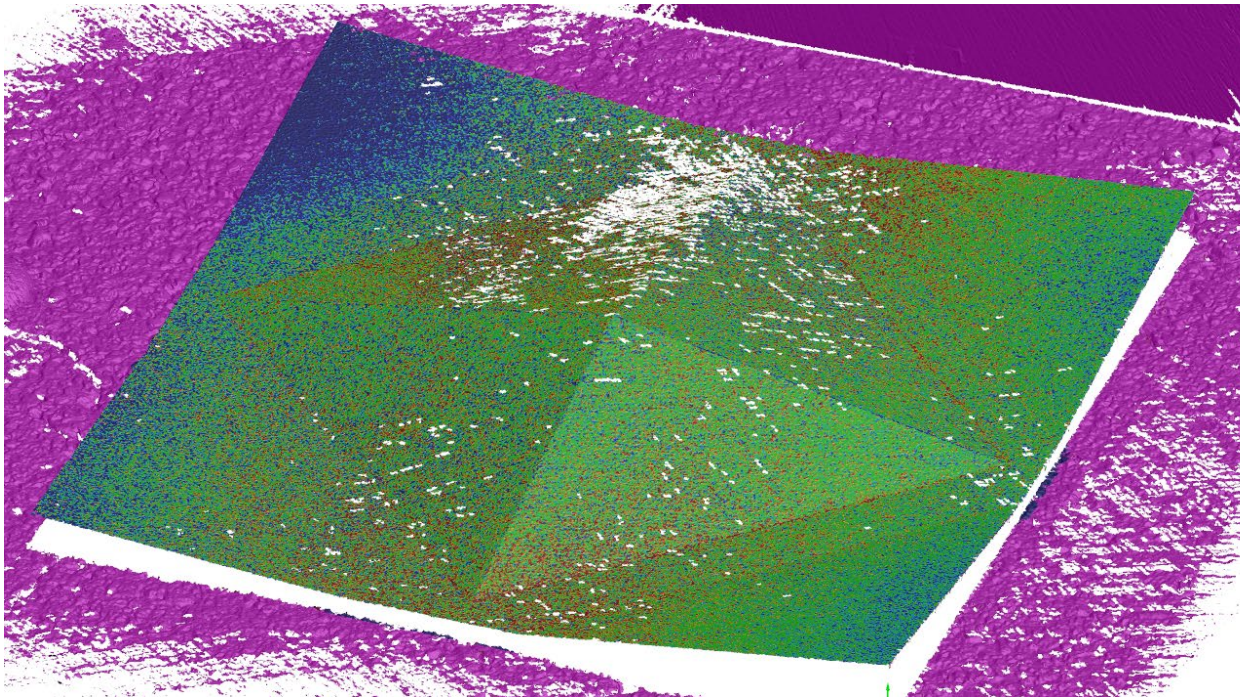
- Only test section where measurements of interest are of a pavement surface
- We need reference measures which are more accurate than the transverse pavement profiler
- We need an an analysis which captures the uncertainty of all measurements

# Ensuring accurate reference data

*Include traceable objects at the time of ground reference data collection*



# Ground Reference Example Scans

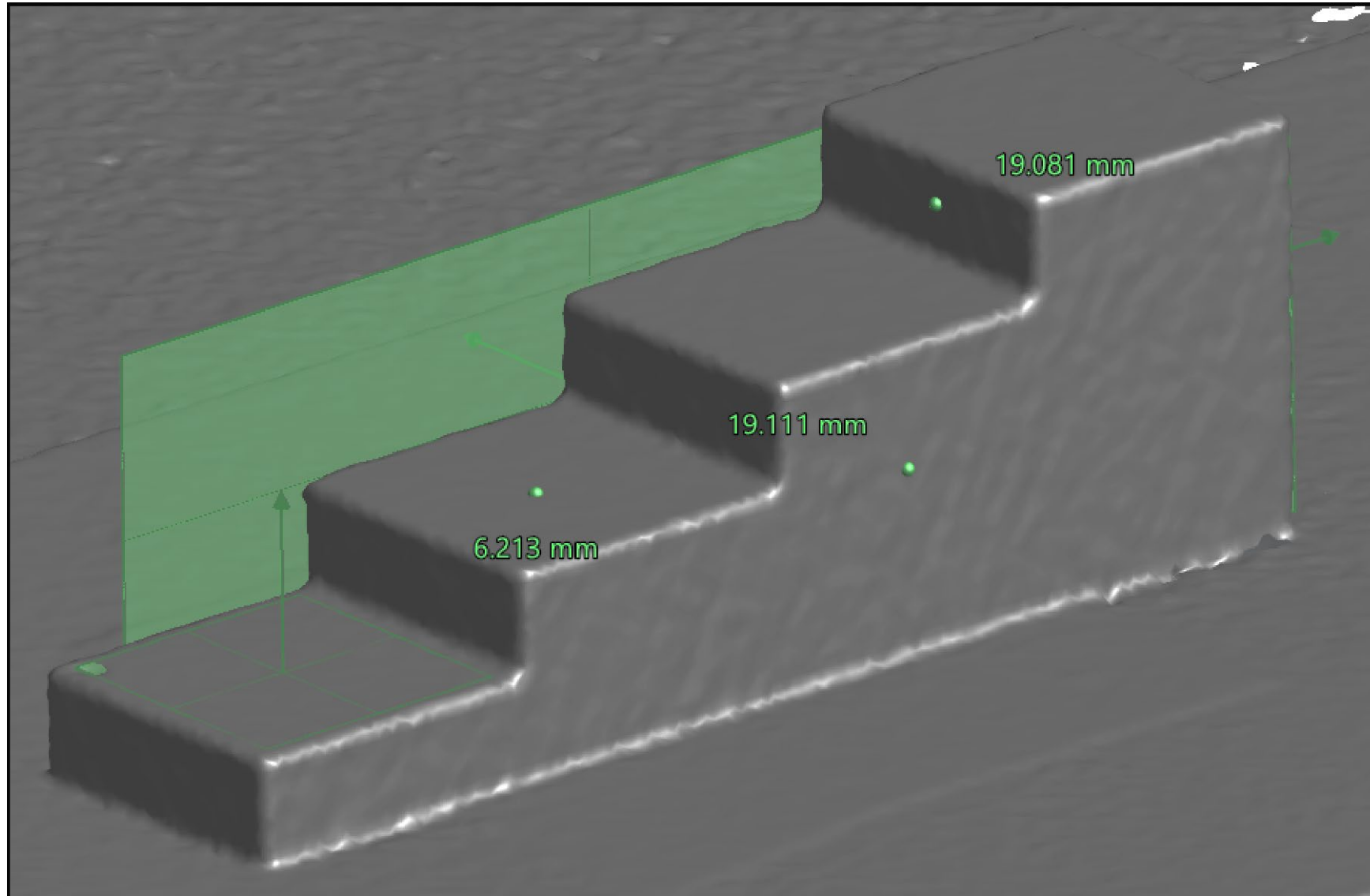


# Ground Reference: Measurement Spacing

Accuracy and Precision Defined as Bias and Confidence Intervals (mm)						
		Lower Bounds (percentile)		Bias	Upper Bounds (percentile)	
		90% (5%)	50% (25%)		50% (75%)	90% (95%)
Transverse Measurement Spacing	<b>Required Vendor</b>					<b>2.0</b> 0.14*
Longitudinal Measurement Spacing	<b>Required Vendor</b>					<b>2.0</b> 0.15*
Vertical Measurement Spacing	<b>Required Vendor</b>					<b>0.03</b> 0.003

\*Adjustable down to 0.05 mm

# Ground Reference: Measurement Error

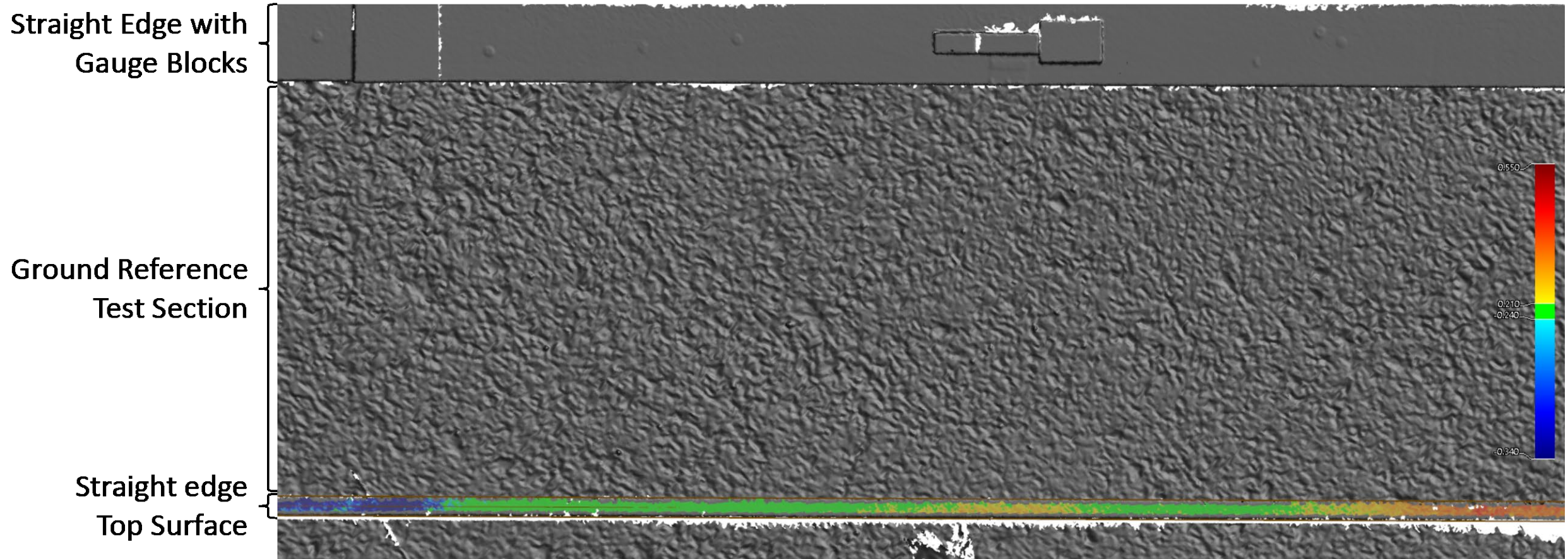




# Ground Reference: Measurement Error

Accuracy and Precision Defined as Bias and Confidence Intervals (mm)						
		Lower Bounds (percentile)		Bias	Upper Bounds (percentile)	
		90% (5%)	50% (25%)		50% (75%)	90% (95%)
Transverse Measurement Error	<b>Required</b> Vendor	<b>-0.30</b> -0.04	<b>-0.15</b> 0.01		<b>0.15</b> 0.07	<b>0.30</b> 0.13
Longitudinal Measurement Error	<b>Required</b> Vendor	<b>-0.30</b> -0.08	<b>-0.15</b> 0.05		<b>0.15</b> 0.09	<b>0.30</b> 0.21
Vertical Measurement Error	<b>Required</b> Vendor	<b>-0.30</b> -0.16	<b>-0.15</b> -0.08		<b>0.15</b> 0.001	<b>0.30</b> 0.08

# Ground Reference: Transverse Straightness & Width

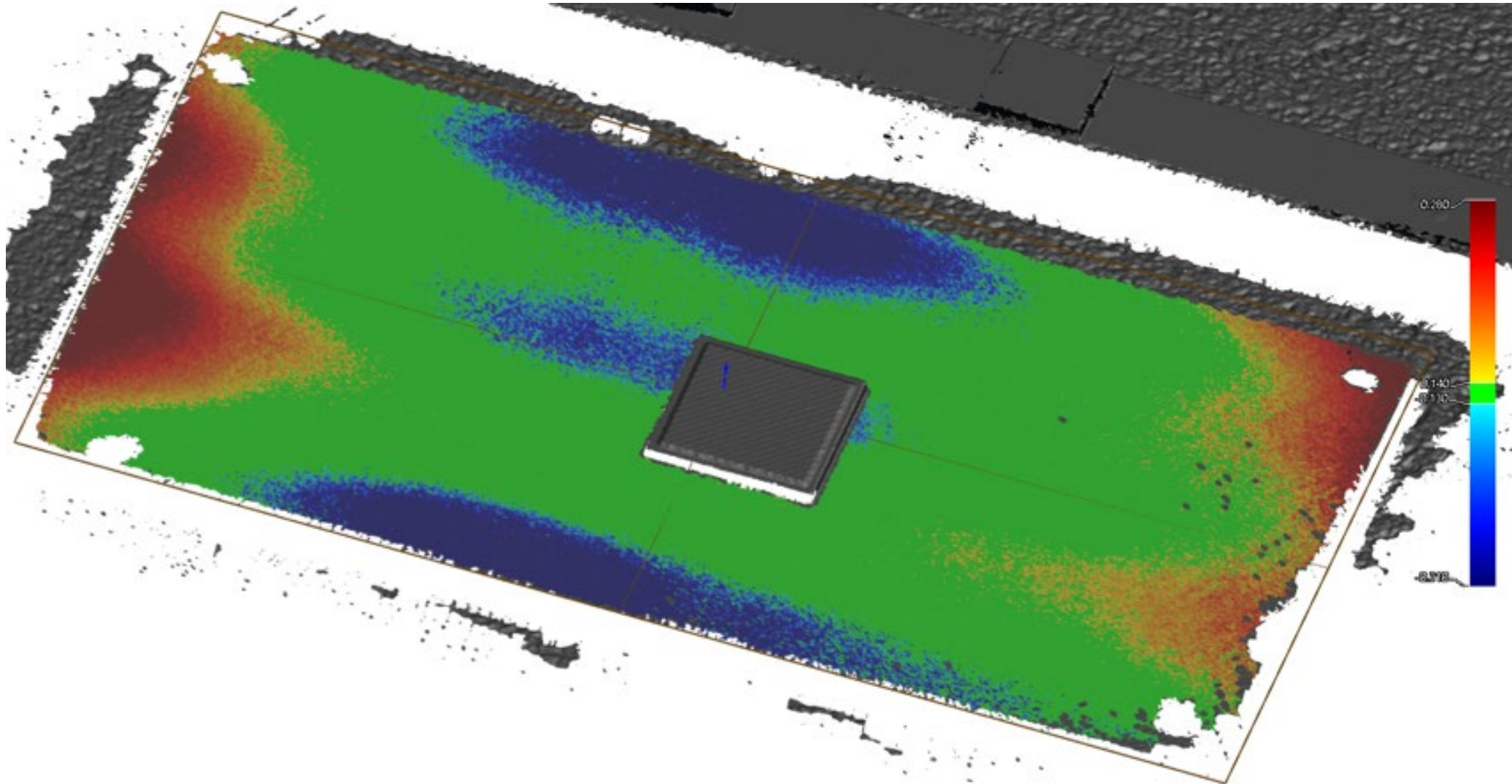


# Ground Reference: Transverse Straightness & Width

Accuracy and Precision Defined as Bias and Confidence Intervals (mm)						
		Lower Bounds (percentile)		Bias	Upper Bounds (percentile)	
		90% (5%)	50% (25%)		50% (75%)	90% (95%)
Transverse Straightness	<b>Required</b> Vendor	<b>-1.0</b> -0.34	<b>-0.5</b> -0.24		<b>0.5</b> 0.21	<b>1.0</b> 0.55
Transverse Width	<b>Required</b> Vendor					<b>4000</b> 4876.8*

\*Limited by 16ft straight edge

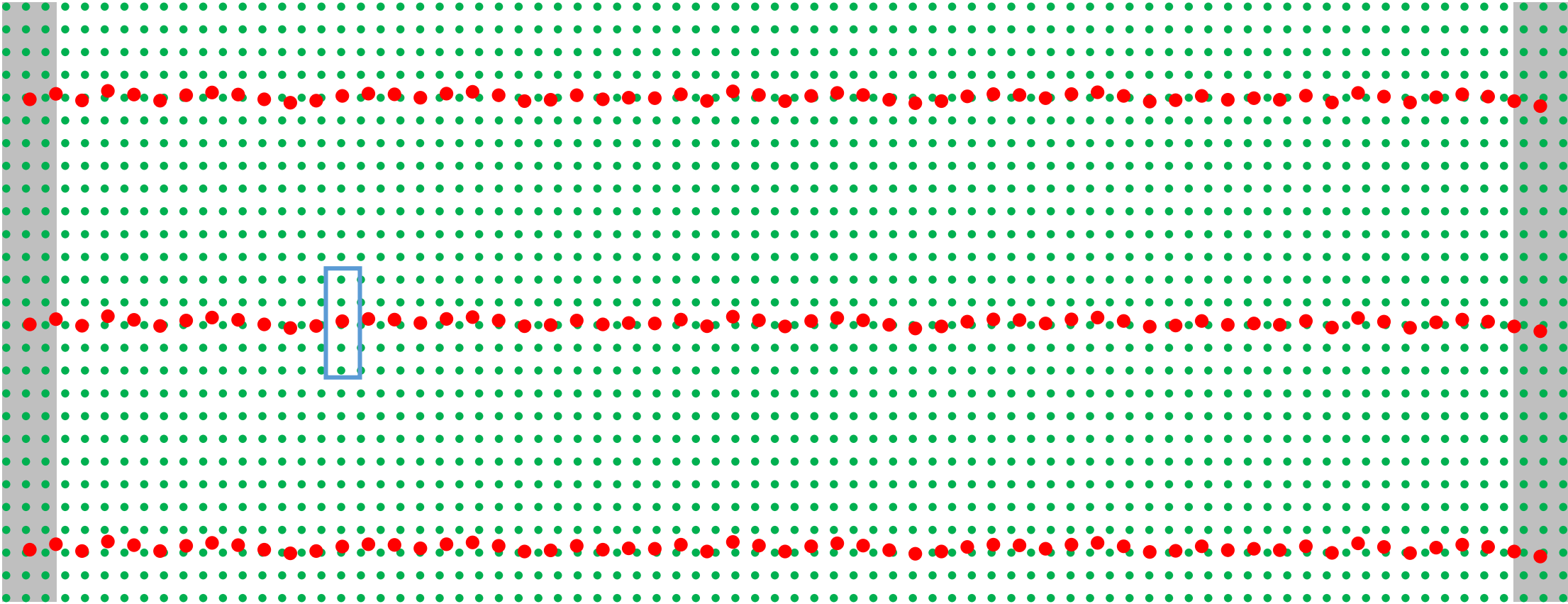
# Ground Reference: Planar Flatness



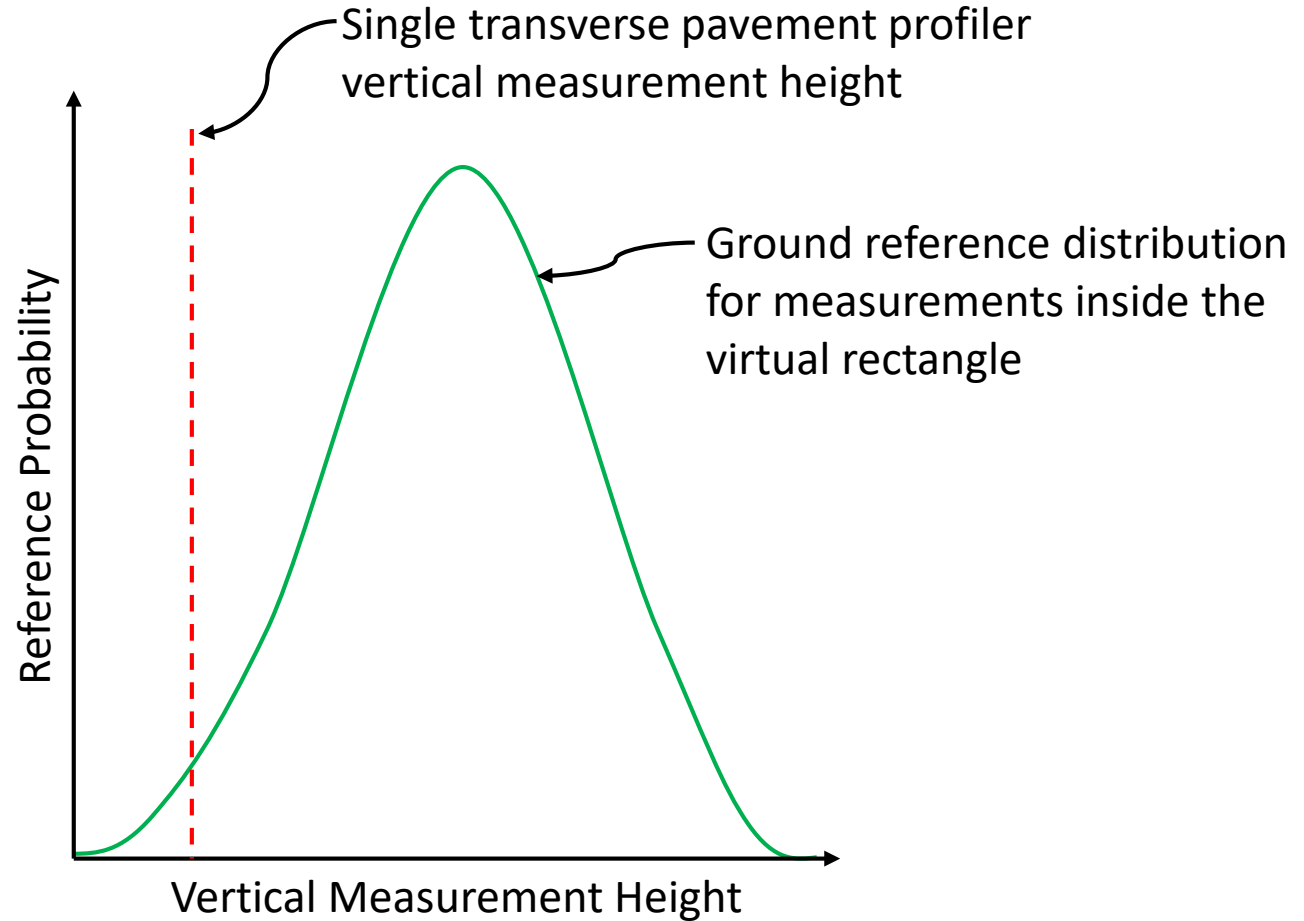
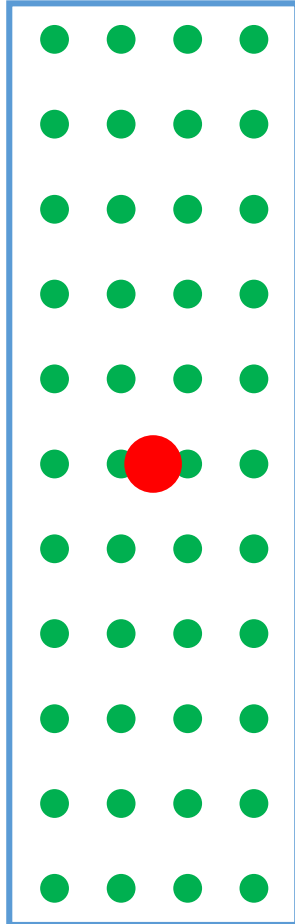
# Ground Reference: Planar Flatness

Accuracy and Precision Defined as Bias and Confidence Intervals (mm)						
		Lower Bounds (percentile)		Bias	Upper Bounds (percentile)	
		90% (5%)	50% (25%)		50% (75%)	90% (95%)
Planar Flatness Error	<b>Required Vendor</b>	<b>-1.0</b> -0.27	<b>-0.5</b> -0.11		<b>0.5</b> 0.12	<b>1.0</b> 0.24

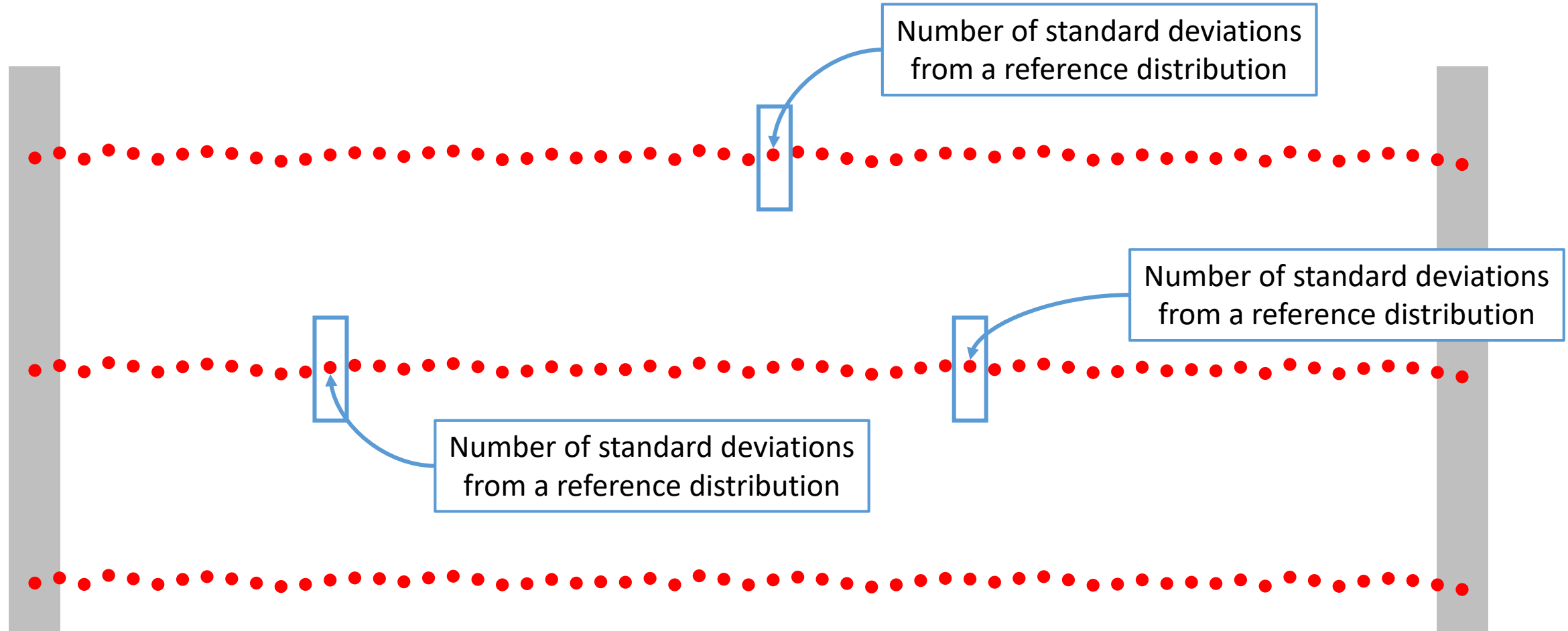
# Analysis Using Ground Reference Data



# Analysis Using Ground Reference Data



# Analysis Using Ground Reference Data



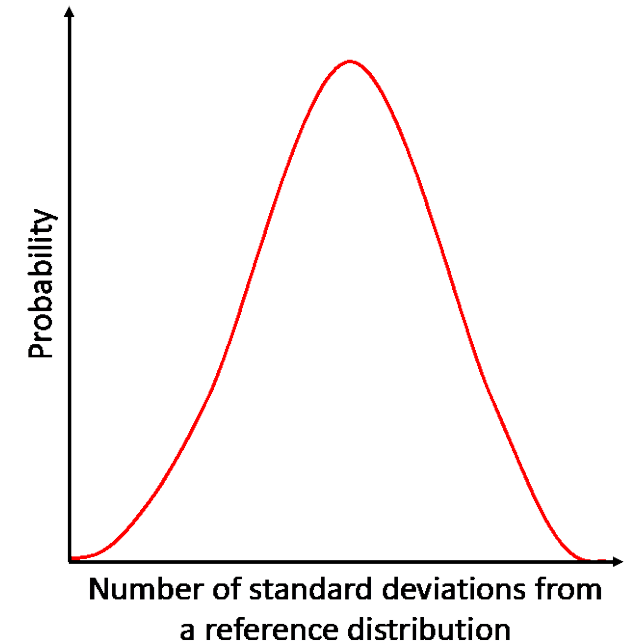
This process can be repeated for a set number of measurements inside the ground reference test section



# Analysis Using Ground Reference Data

Analysis of each individual measurement can be summarized in a single distribution.

A set of confidence interval requirements can be made for this resulting distribution.



Accuracy and Precision (Standard Deviations from a Reference Distribution)					
	Lower Bounds (mm)		Bias	Upper Bounds (mm)	
	90% (5%)	50% (25%)		50% (75%)	90% (95%)
Point Cloud Vertical Error	-2.5	-1.0	NA	1.0	2.5
Gridded Data Vertical Error	-1.7	-0.7	NA	0.7	1.7

# Thank you for your time

## Questions?

Contact:

Craig Altmann

[altmanct@vt.edu](mailto:altmanct@vt.edu)