

# NEW YORK



THE RACE TO BETTER DATA  
APRIL 25TH-28TH, SARATOGA SPRINGS

## Implementing Transverse Pavement Profiler

**John B. Ferris, Ph.D.**  
VTech and Road Scholar Solutions

## Certification Standards



# Implementing Transverse Pavement Profiler Certification Standards

John B. Ferris, Ph.D.

Assoc. Prof., Mechanical Engineering  
Director, Vehicle Terrain Performance Lab



John B. Ferris, Ph.D.

Managing Member  
Road Scholar Solutions, LLC



# Outline

Overview, Definitions and Approach

Transverse Pavement Profiler (TPP) Assessment Tests

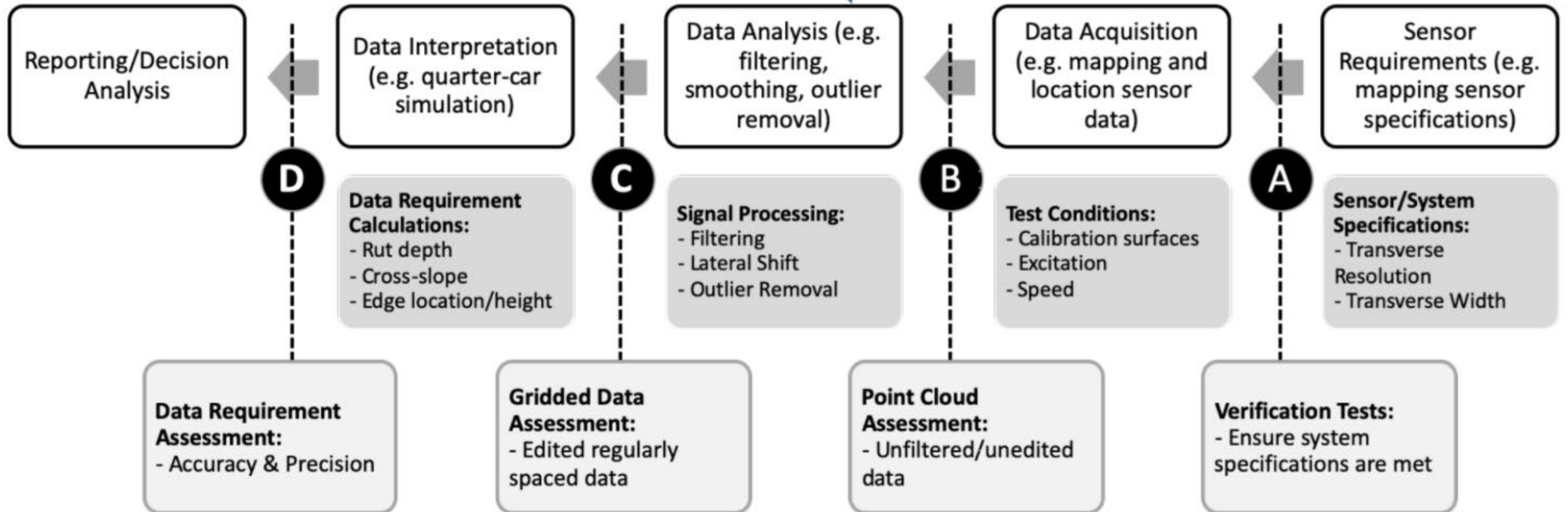
Ground Reference Equipment (GRE) Measurements

Assessment of GRE and TPP

# Overview

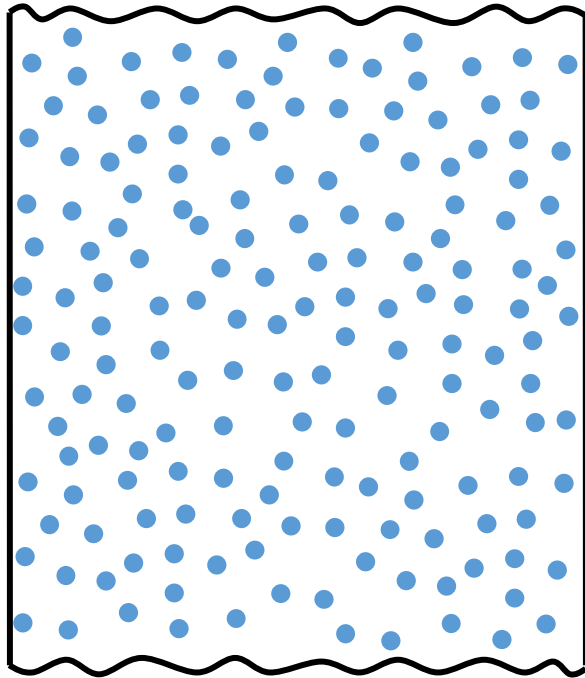
## Requirements Definition

## Process Flow

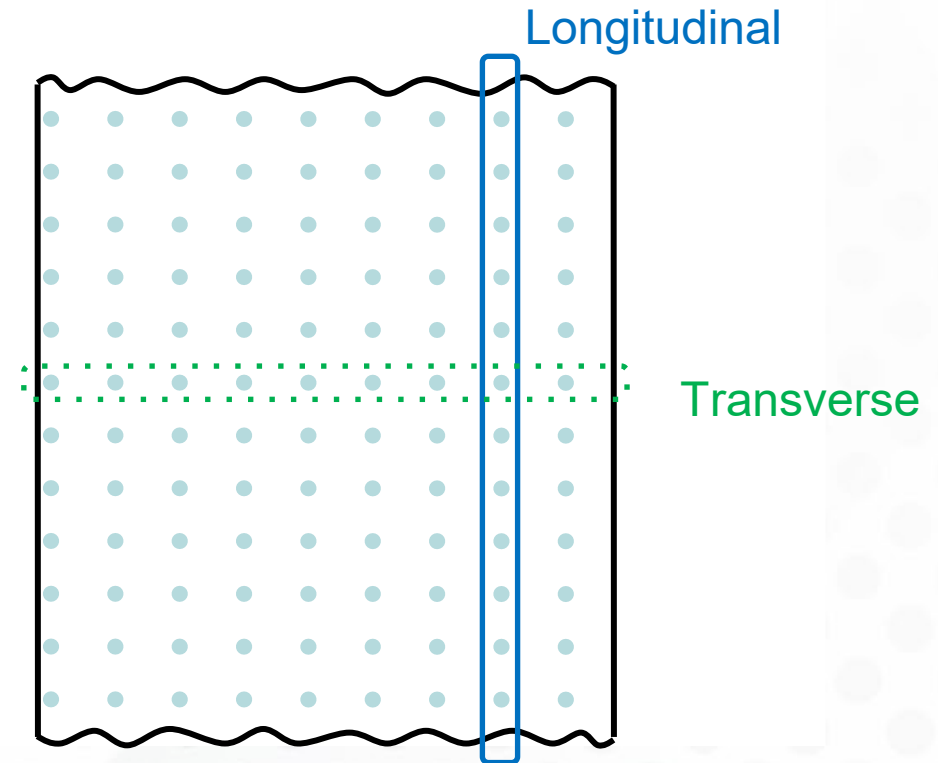


# Definitions

Point Cloud



Gridded Data



Top View

# Definitions

Mapping Sensor	Localization Sensor
<i>measure road surface relative to TPP coordinates</i>	<i>georeference TPP system in global coordinates</i>
<b>Examples:</b> <ul style="list-style-type: none"><li>• Laser/Lidar</li><li>• Camera</li><li>• Radar</li></ul>	<b>Examples:</b> <ul style="list-style-type: none"><li>• Inertial Nav. (GPS, IMU)</li><li>• Accelerometers</li></ul>

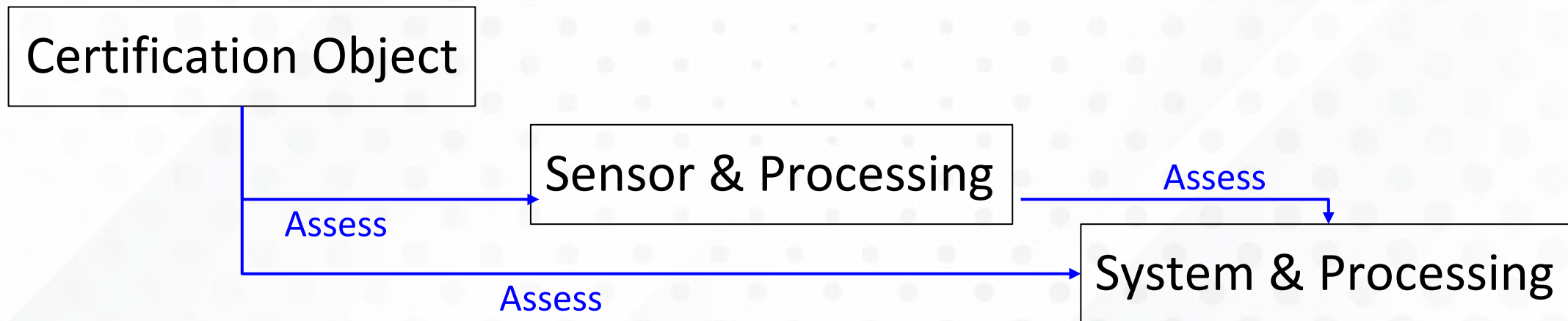
Fused to form georeferenced road surface data



# Approach

## *Chain of Traceability to Certification Objects*

- Certification Objects
  - Dimensions measured by a certified laboratory (NIST, ISO...)
  - Dimensions known to some accuracy and precision traceable to Cert. Lab



- Subsequent assessments limited by the accuracy of previous step

# TPP Assessment Tests

## **Static performance**

Evaluate static road surface measurement ability  
Assess mapping sensors

## **Body motion cancelation**

Evaluate ability to remove body movement  
Assess localization sensors, fuse mapping and localization

## **Navigation drift mitigation**

Evaluate drift in global position  
Assess localization sensors, fuse localization sensors

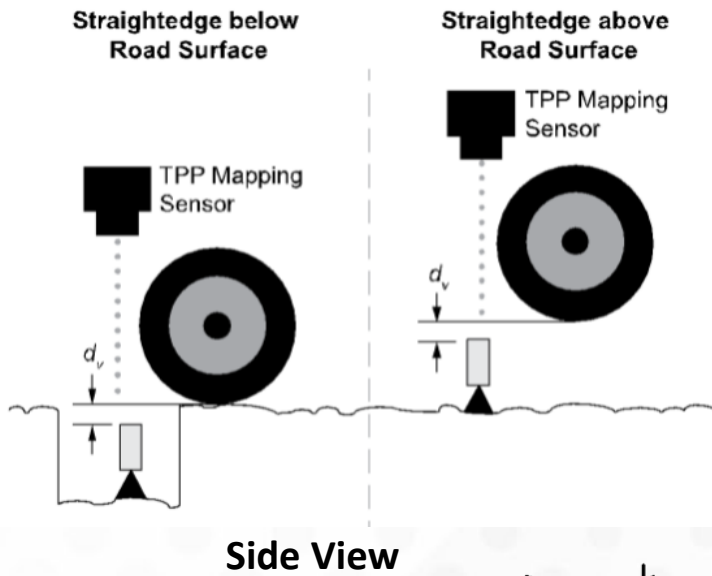
## **Typical highway**

Evaluate complete TPP during typical highway operations

- Transverse Capability
- Ground Reference\*



# Static Performance



Assess:

- Mapping sensors (lasers)

## Output Test Statistics

Transverse Measurement Resolution

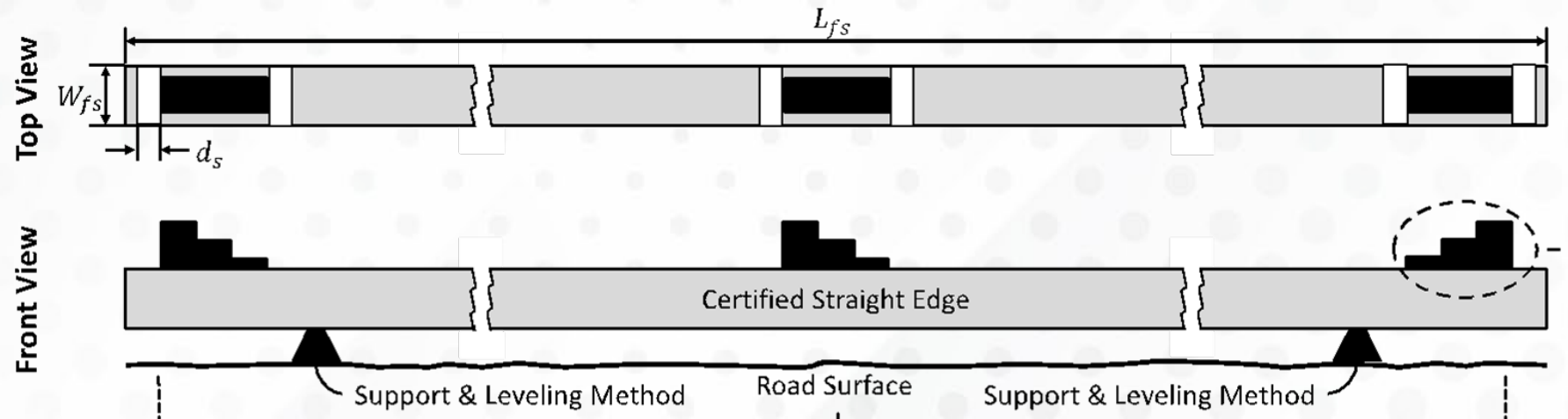
Transverse Measurement Error

Vertical Measurement Resolution

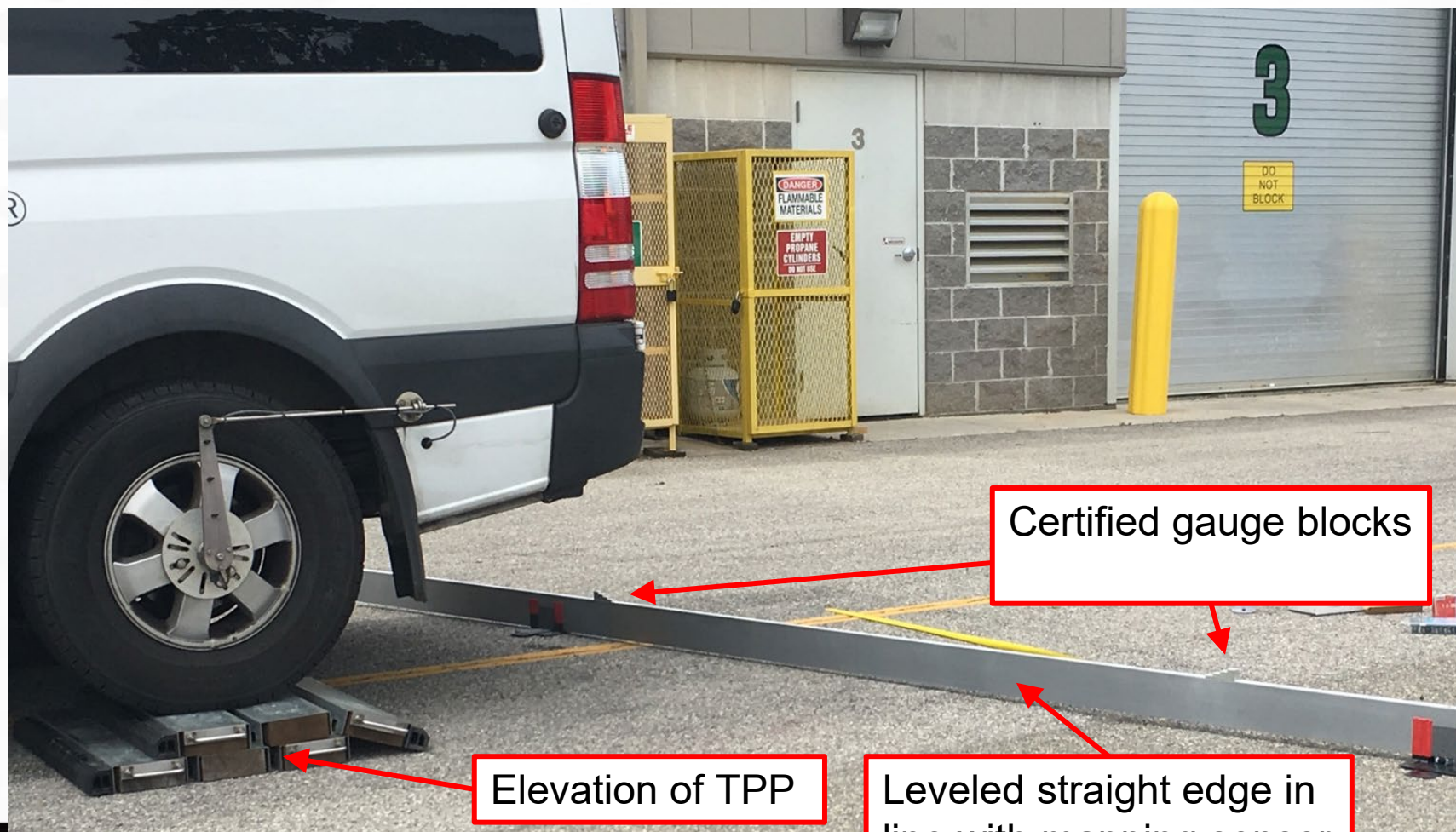
Vertical Measurement Error

Total Transverse Width

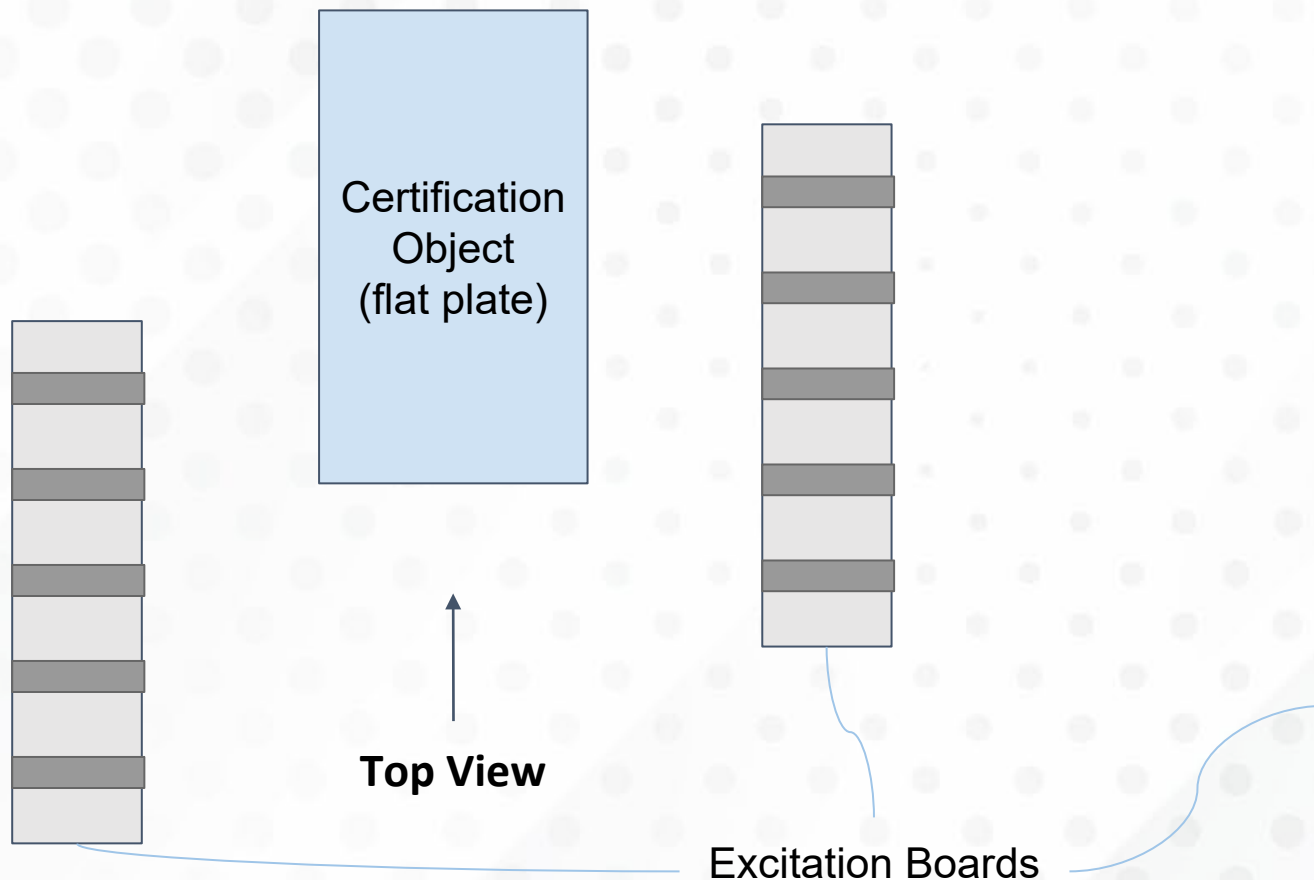
Straightness Error



# Static Performance



# Body Motion Cancelation



Output Test Statistics

Vehicle Body Motion Error

Assess:

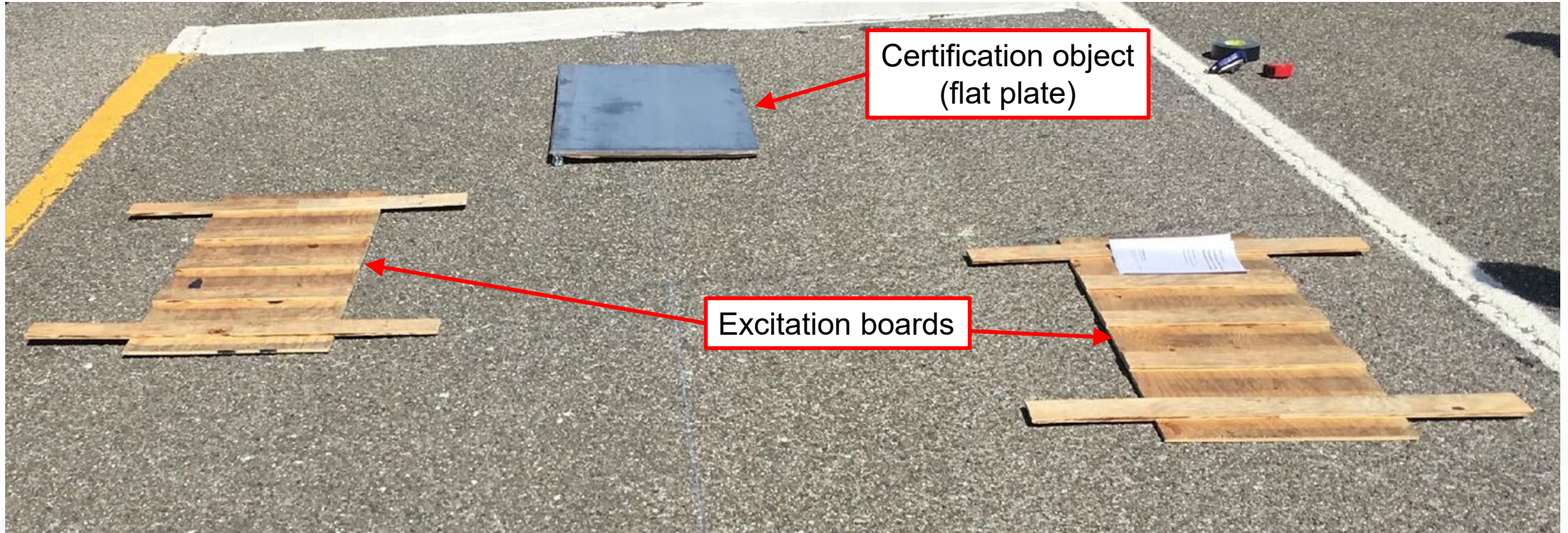
- Localization sensors (IMU/gyro, accels)
- Processing: Fuse mapping and localization sensors

Induce:

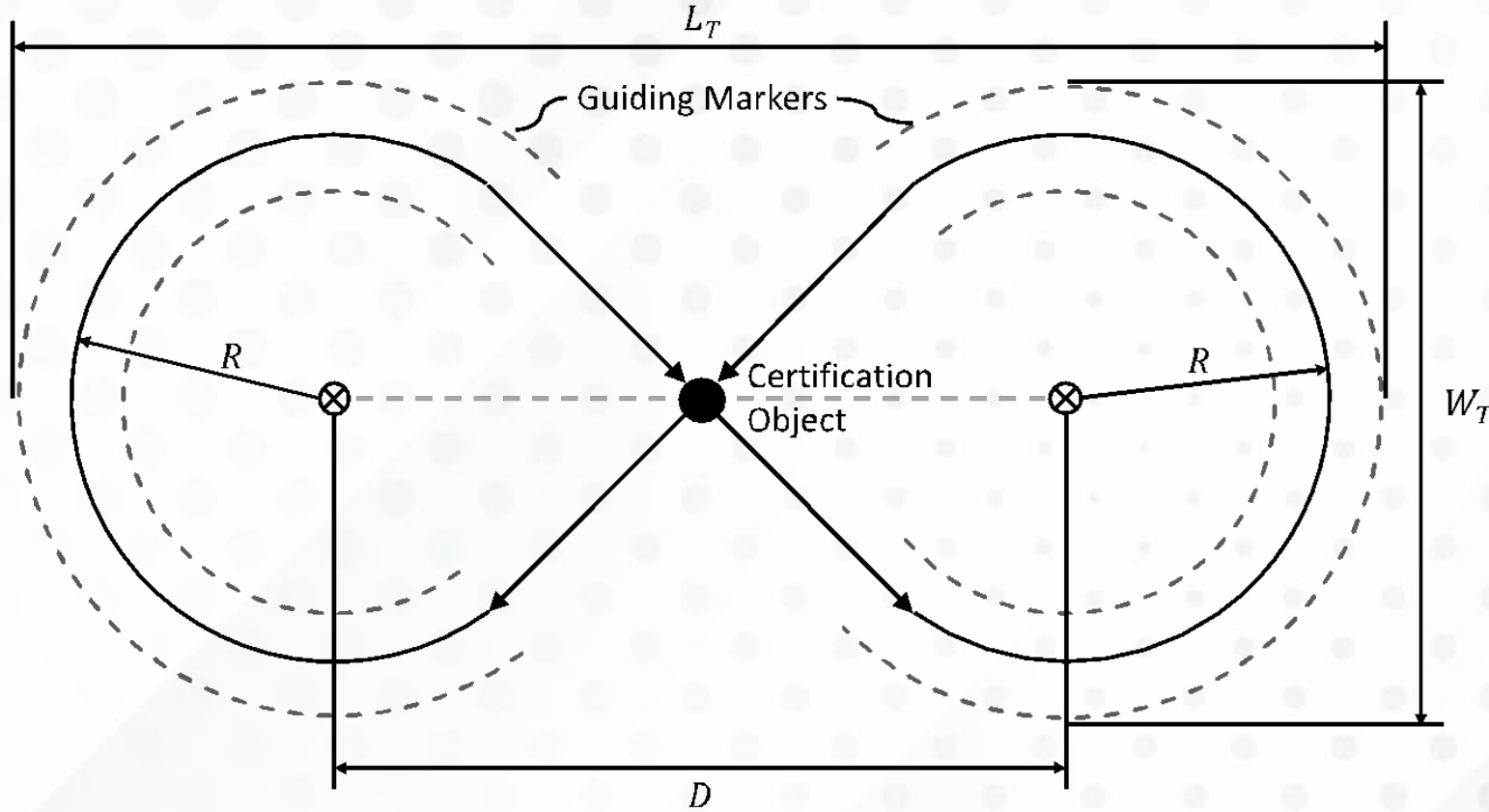
- Roll
- Pitch
- Primary Bounce ( $\sim 1.5$  Hz)
- Secondary Bounce ( $\sim 15$  Hz)



# Body Motion Cancellation



# Navigation Drift Mitigation



Top View

## Output Test Statistics

Easting Position Error

Northing Position Error

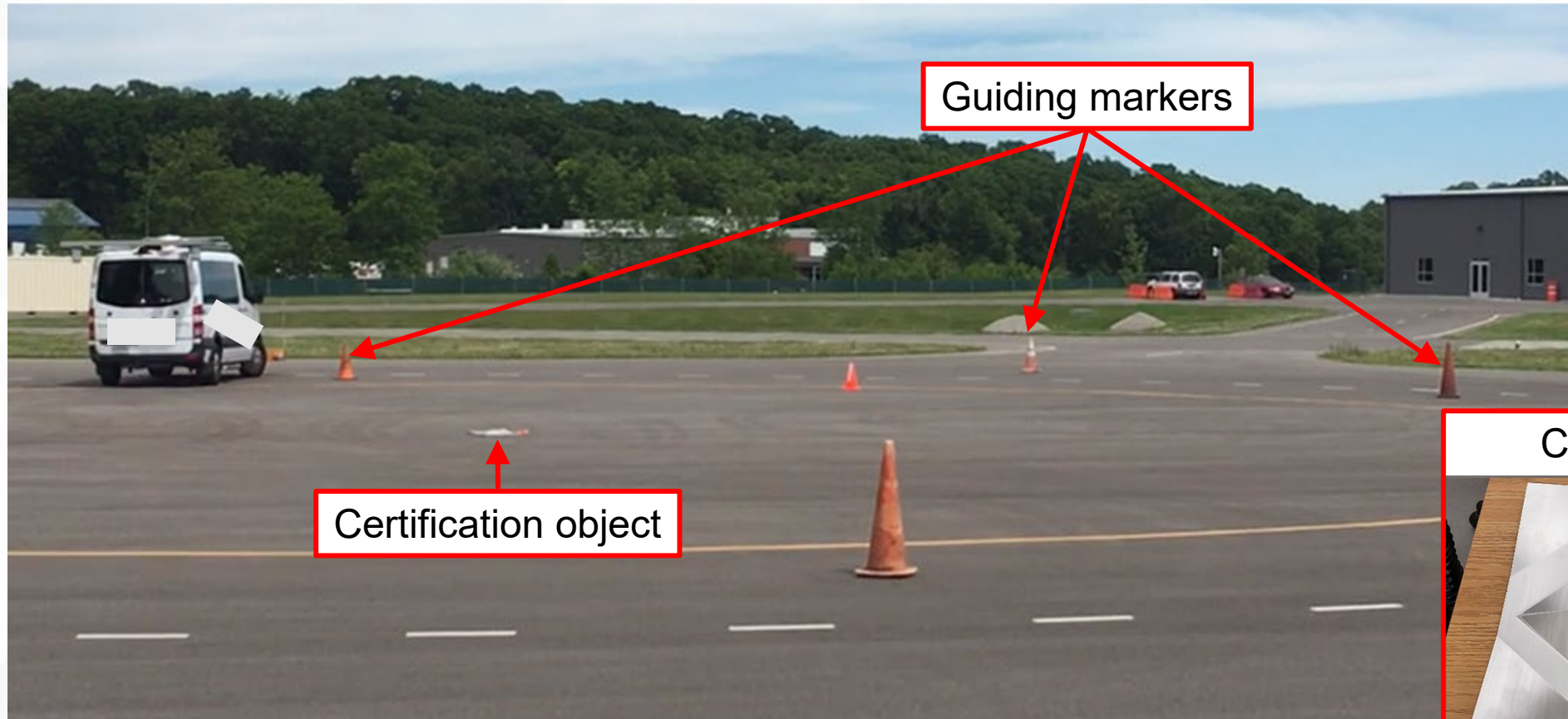
Elevation Position Error

## Assess:

- Localization sensors (GPS, IMU/gyro, accels)
- Processing: Fuse various localization sensors

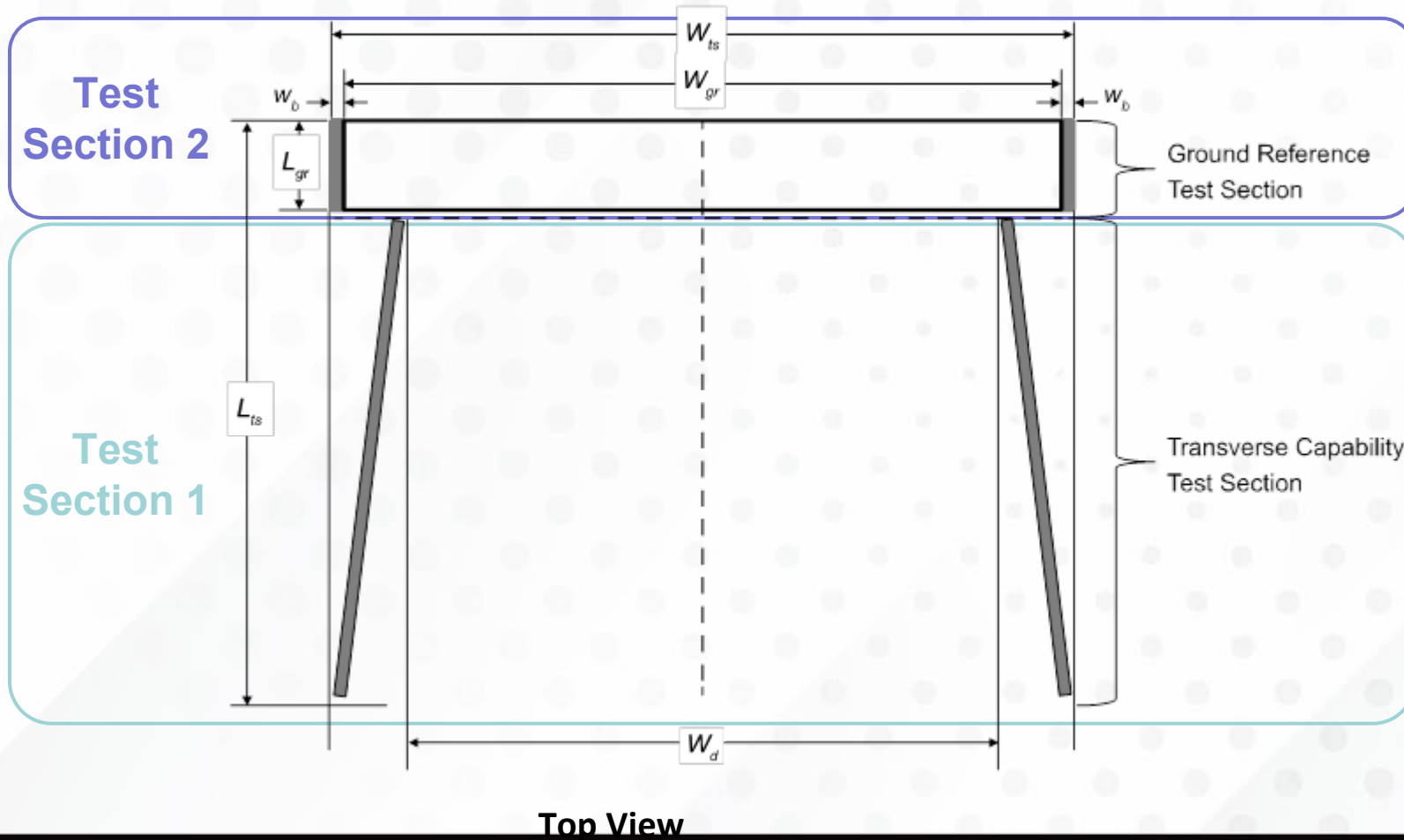


# Navigation Drift Mitigation





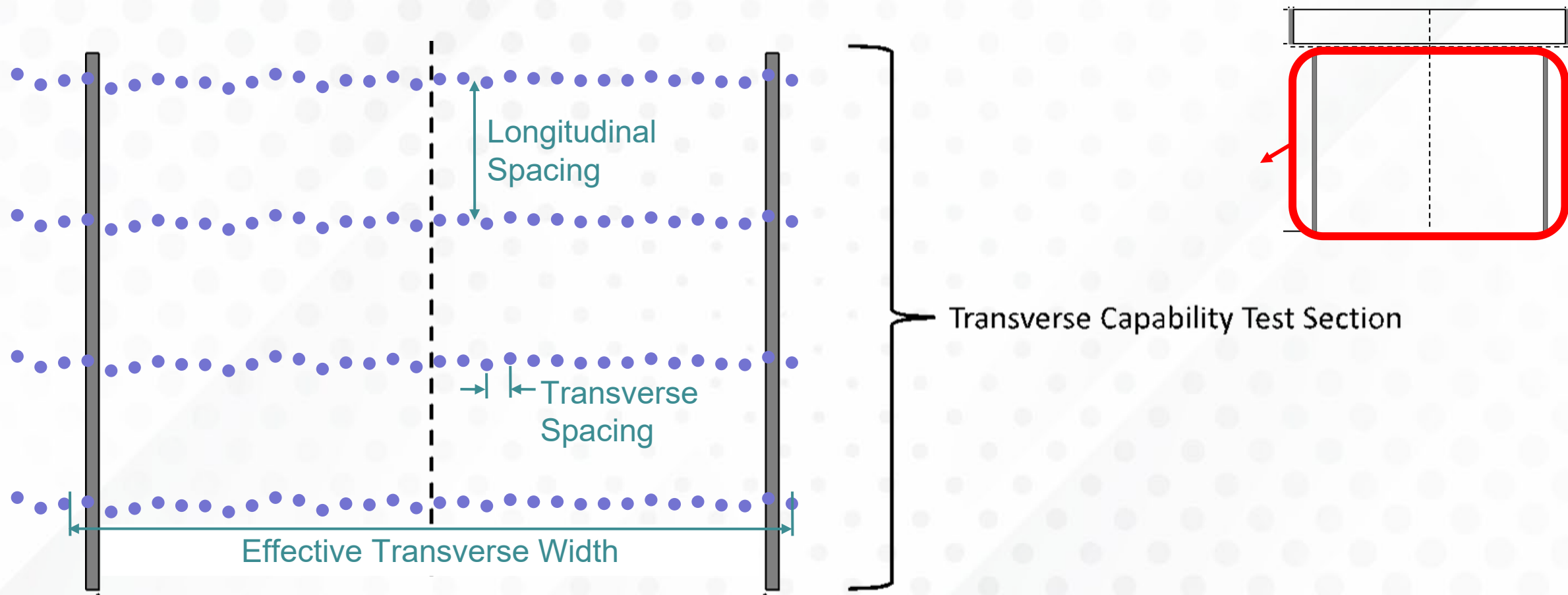
# Typical highway performance



## Output Test Statistics

Transverse Measurement Spacing <sup>1</sup>
Effective Transverse Width <sup>1</sup>
Vertical Measurement Spacing <sup>1</sup>
Longitudinal Measurement Spacing <sub>1</sub>
Point Cloud Vertical Error <sup>2</sup>
Gridded Data Vertical Error <sup>2</sup>
Cross Slope Error <sup>2</sup>
Rut Depth Error <sup>2</sup>
Edge/Curb Transverse Location Error <sup>2</sup>
Edge/Curb Vertical Magnitude Error <sub>2</sub>

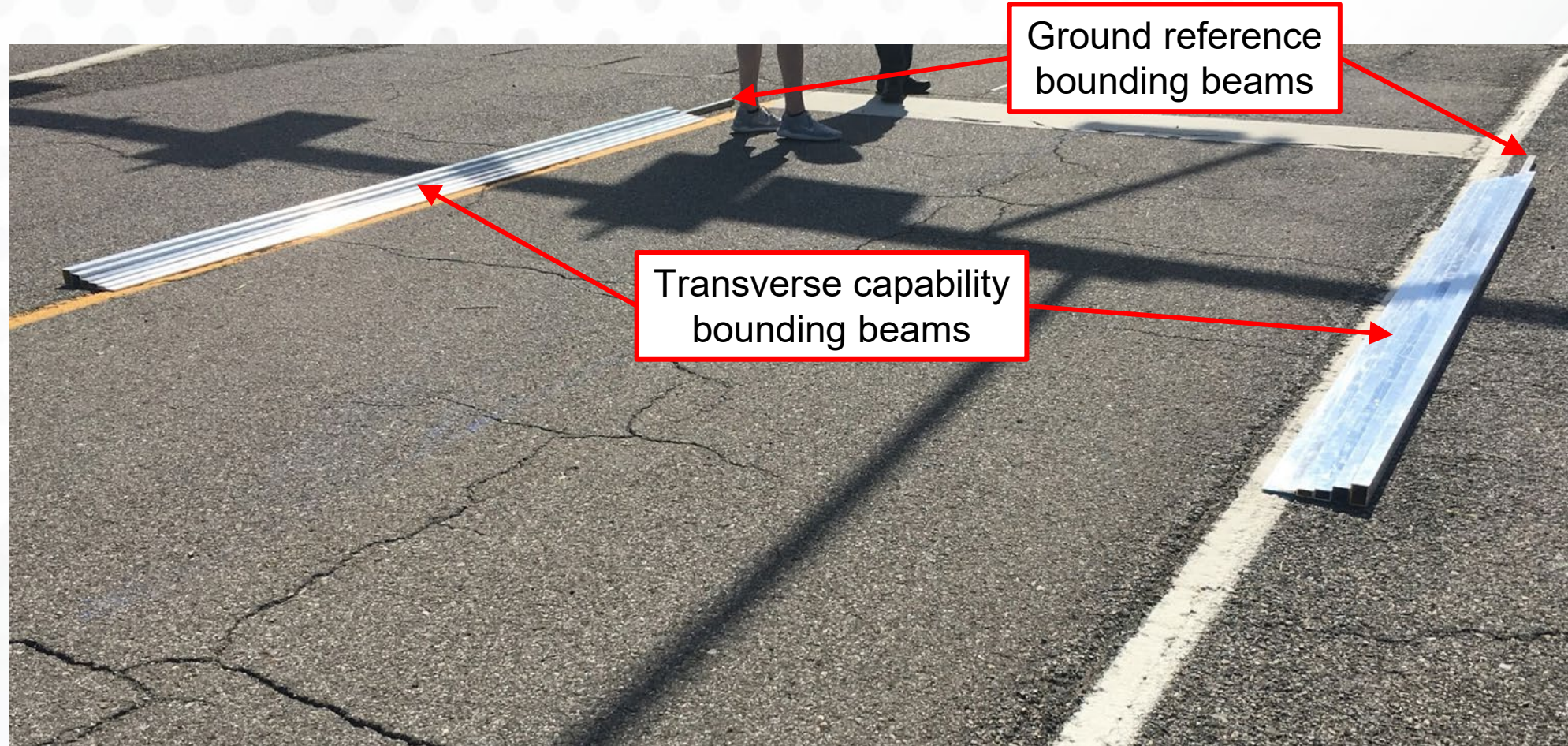
# Transverse Capability Test – Section 1



Top View



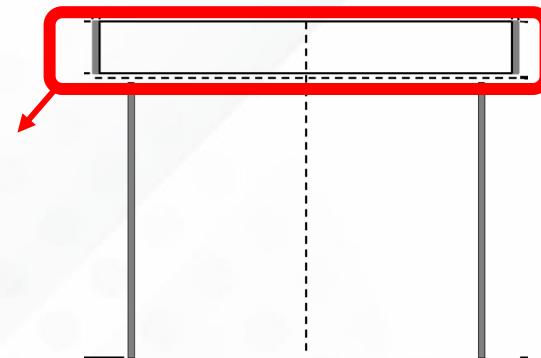
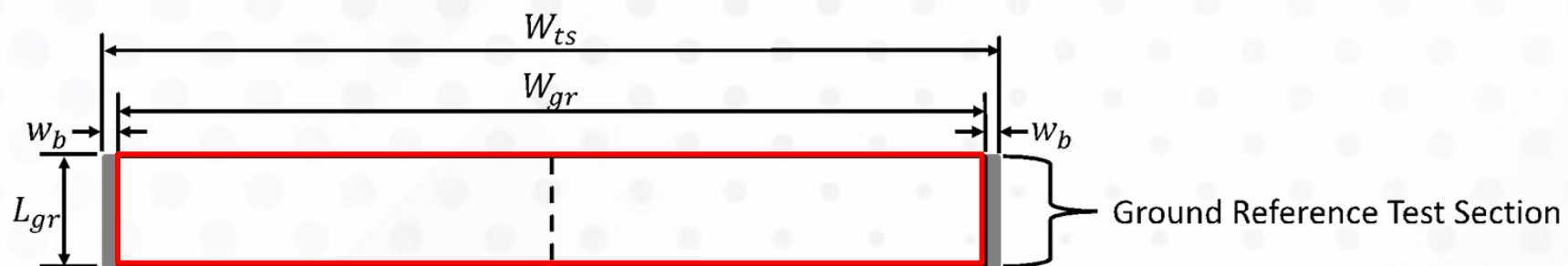
# Typical highway performance





# Ground Reference Test – Section 2

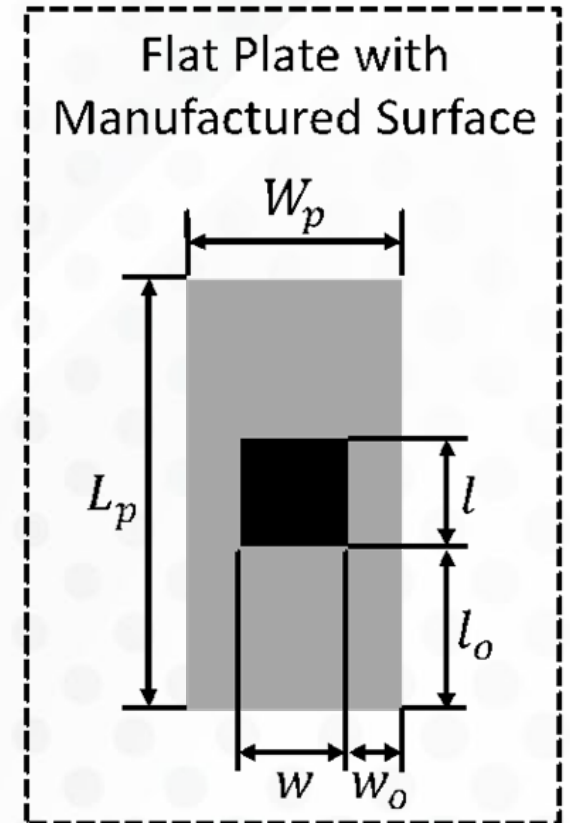
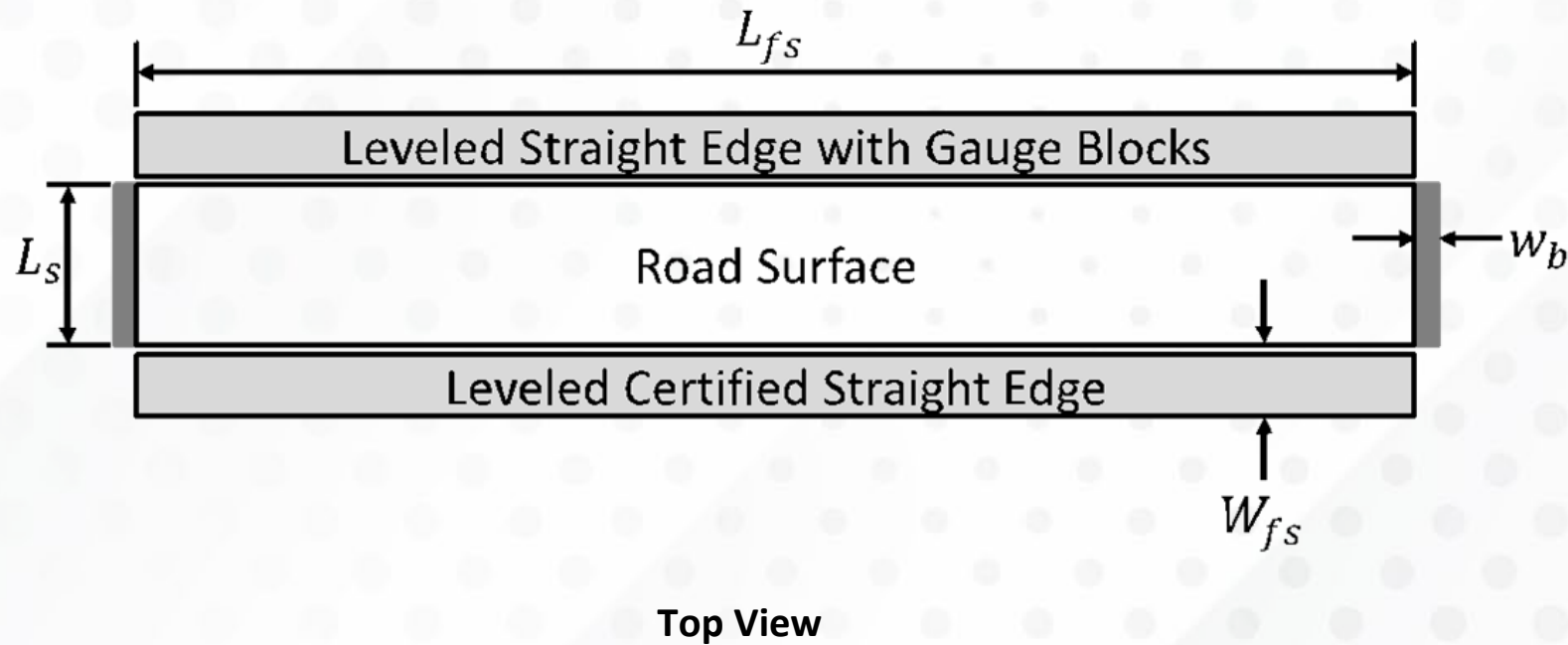
*Section with **reference** measurements is required*



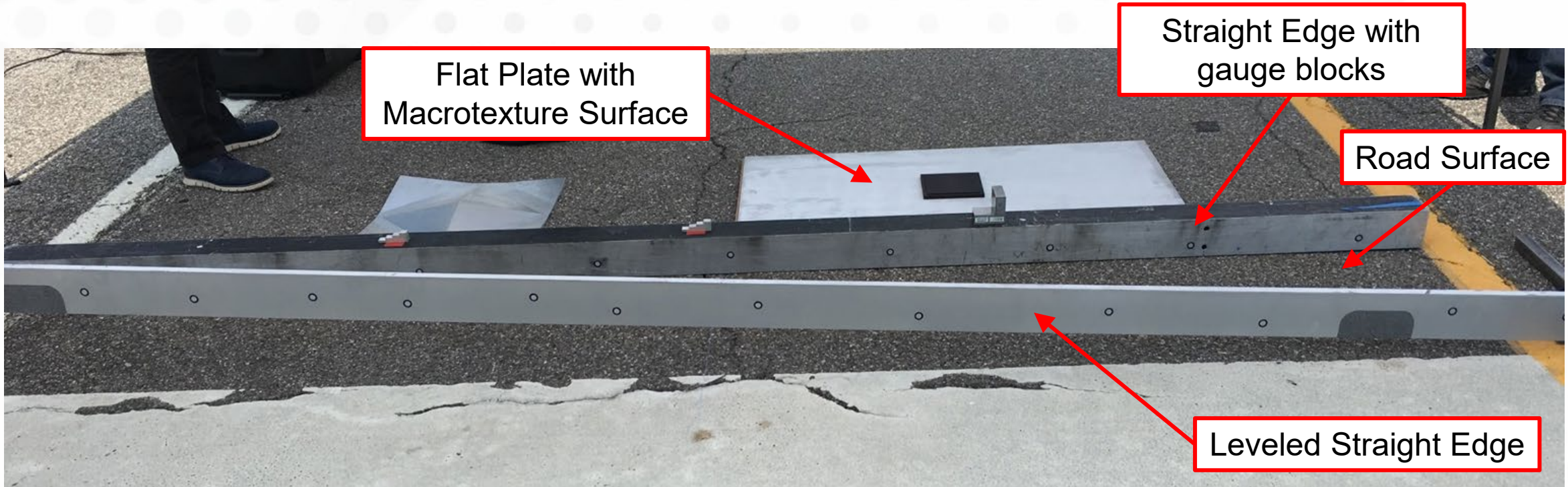
Top View

# Acceptance of GRE Measurements

*Use the proposed TPP certifications as a guide for developing GRE certifications*



# Acceptance of GRE Measurements

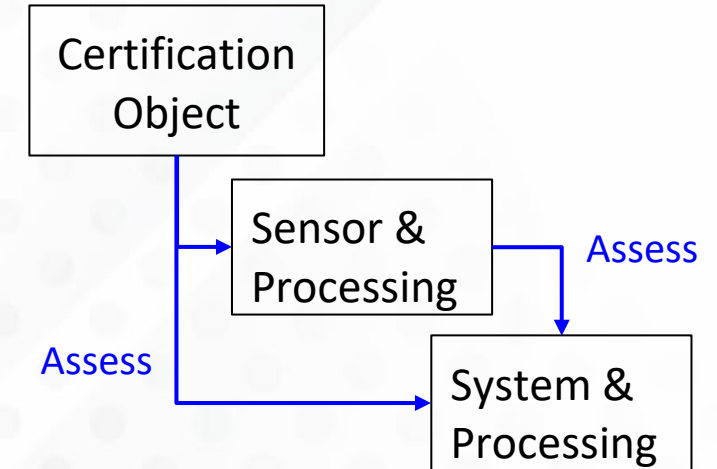




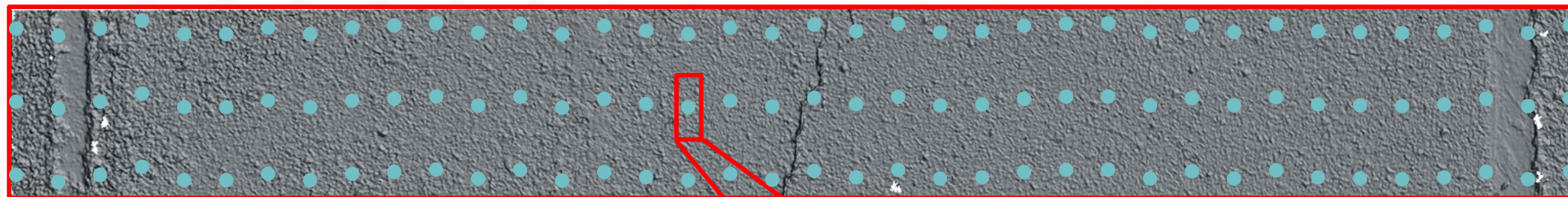
# Acceptance of GRE Measurements



Recall Chain of Traceability:

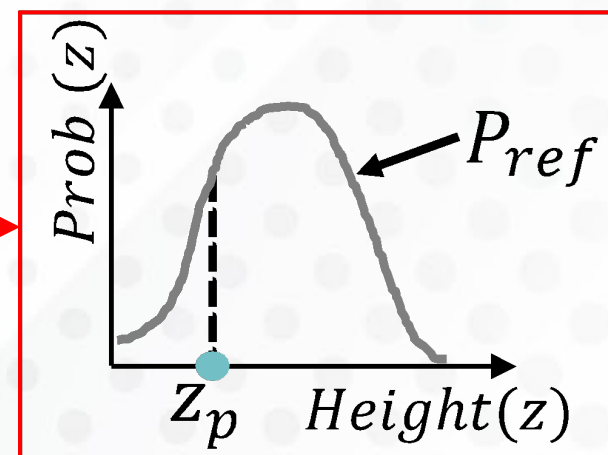
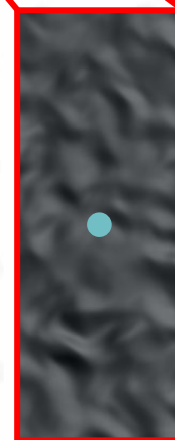


# Ground Reference Test: TPP Measurements



Top View

*Account for uncertainty  
in measurements*





# Precision and accuracy of TPP vs Requirements

## Data Requirements *Requirements Statement (RS)*

Accuracy and Precision					
	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	-1.5	NA	1.5	2.5

## TPP Capabilities *Capability Statement (CS)*

Accuracy and Precision					
	Lower Bounds (mm)		Bias	Upper Bounds (mm)	
	90% (5%)	50% (25%)		50% (75%)	90% (95%)
Transverse Measurement Error					
Vertical Measurement Error					
Transverse Measurement Resolution					
Vertical Measurement Resolution					
⋮					

# Summary

- Tests for Transverse Pavement Profiler (TPP)
- Overview of Ground Reference Equipment
- Assessment of TPP Capabilities with respect to Requirements

Thank you