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TRANSPORTATION RESEARCH BOARD

# How to Certify and Verify Pavement Surface Condition Data

**June 10, 2020**

**@NASEMTRB**
**#TRBwebinar**

# PDH Certification Information:

- 1.5 Professional Development Hours (PDH) – see follow-up email for instructions
- You must attend the entire webinar to be eligible to receive PDH credits
- Questions? Contact Reggie Gillum at RGillum@nas.edu

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REGISTERED CONTINUING EDUCATION PROGRAM

**#TRBwebinar**

# Learning Objectives

1. Identify current practices for certification and verification of pavement condition data using advanced mapping sensor technology
2. Discuss limitations of various technologies and list solutions to overcome limitations
3. Consider data quality when making pavement management decisions
4. List sources available for further investigation and knowledge acquisition on these topics

**#TRBwebinar**

# Example Data Collection Vehicles

# TRB How to Certify and Verify Pavement Surface Condition Data – State of the Practice of Pavement Condition Data

*June 10, 2020*

**Andrew Mergenmeier, P.E.**
**Senior Pavement and Materials Engineer**
**U.S. Department of Transportation**
**Federal Highway Administration**
**Resource Center**

# Outline – Highway Speed Data Collection

- Data Collection System Certification and Verification
- State of Practice for Ride, Rutting, Cracking, and Faulting

# How to Certify and Verify Pavement Condition Data

- Data collection equipment/personnel certification
- Data quality control measures to be conducted before data collection begins and periodically during the data collection program
- Data sampling, review and checking processes
- Error resolution procedures and data acceptance criteria

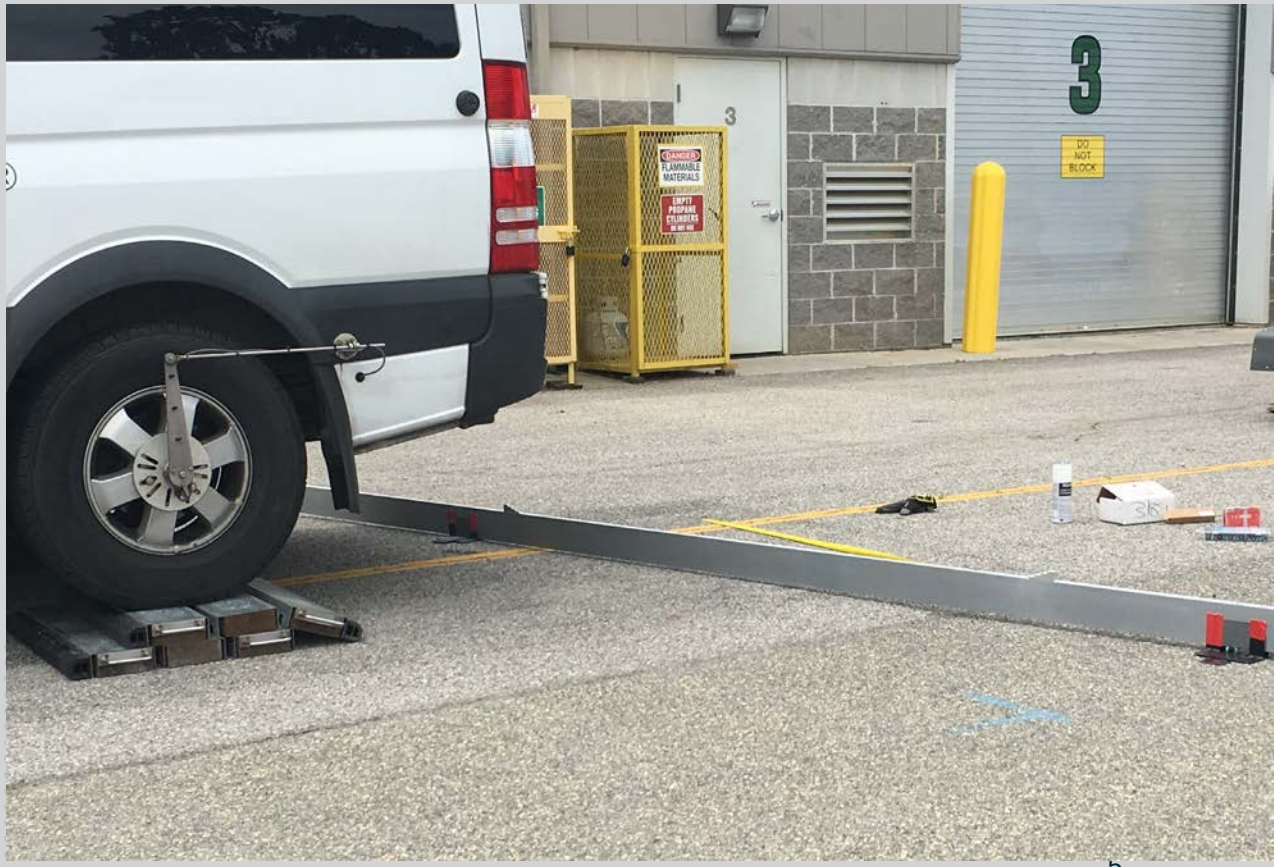
*Image source: Pixabay*

# Pavement Surface Condition Data

- Ride Quality (IRI), Rutting, Cracking, and Faulting
- Before Production Data Collection
- Certification:  A procedure to evaluate the data collected by the equipment and operators in accordance with a **nationally recognized standard** to check the accuracy and precision of the collected data with respect to reference measurements.
- Validation:  A procedure performed to evaluate the data collected by the equipment or operators in comparison with reference measurements under representative conditions. Best Practice

# Ride Quality (IRI)

- AASHTO R56 - Certification of Inertial Profiling Systems
- Developed via Pooled Fund Study – over 10 years




Source: FHWA

# Rutting, Cracking and Faulting

TPF-5(299)/(399) 24 State DOT's (FHWA Administered): Improve the Quality of Pavement Surface Distress and Transverse Profile Data Collection and Analysis by assembling SHAs, the FHWA, and industry representatives to:

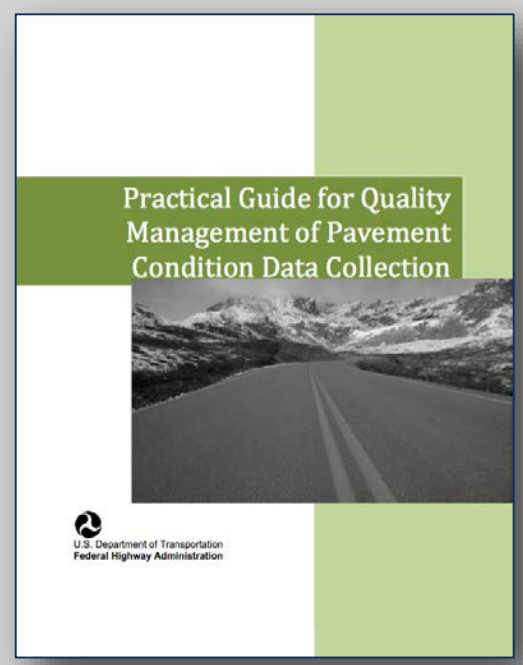
- Identify data collection integrity and quality issues
- Identify data analysis needs
- Suggest approaches to addressing identified issues and needs

Based on this information, the SHAs and the FHWA will:

- Initiate and monitor projects intended to address identified issues and needs
- Disseminate results
- Assist in solution deployment

# List of a Few Best Practices Resources

- FHWA Practical Guide
  - Detailed guidance on pavement data quality
- NCHRP Synthesis 401 and 531
  - Data quality approaches
  - Review of the state of practice




- FHWA Interstate Highway Pavement Sampling Quality Management Plan

# Rutting

- TPF-5(299) Calibration, Certification, and Verification of Transverse Pavement Profile Measurements
  - Rut, Cross Slope, Edge Condition
  - Standards submitted to AASHTO
  - Final Report to be published 2020

# Cracking

- TPF-5(299) Developing Guidelines for Cracking Assessment for Use in Vendor Selection Process for Pavement Crack Data Collection/Analysis Systems and/or Services – final report to be published 2020

# Faulting

- TPF-5(299) Jointed Concrete Pavement Faulting Collection and Analysis Standards – field testing summer/fall 2020

# Additional National Activities

FHWA National/Regional Certification Workshops – planned for 2021

NCHRP ongoing project:

01-60 “Measuring the Characteristics of Pavement Surface Images and Developing Standard Practices for Calibration, Certification, and Verification of Imaging Systems”

# Conclusion

- Many ongoing and planned national activities to support equipment/personnel certification and verification
- Stay engaged to accelerate the learning curve and implementation

# Questions?

**Andrew Mergenmeier P.E.**
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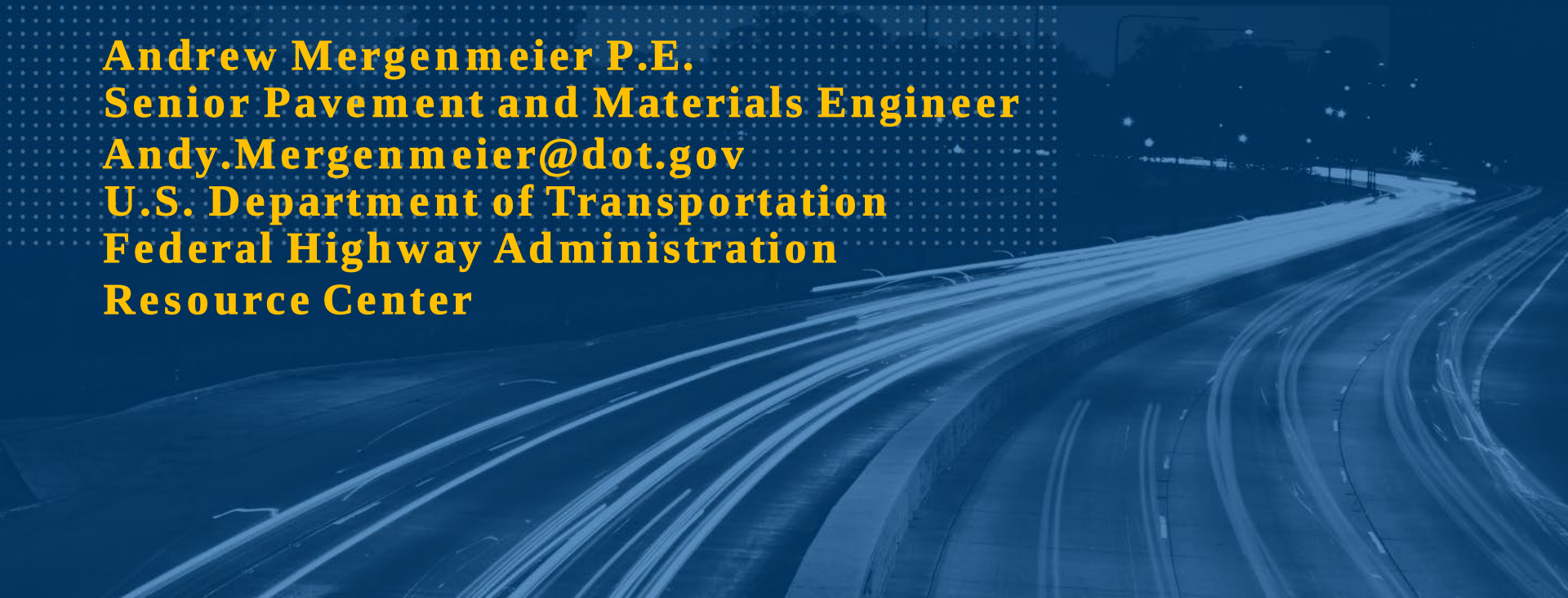
**Andy.Mergenmeier@dot.gov**
**U.S. Department of Transportation**
**Federal Highway Administration**
**Resource Center**



# Calibration & Validation of Highway and Street Distresses

Doug Frith, P.E.
Quality Engineering Solutions, Inc.
June 10, 2020

# Acknowledgements

***TPF-5(299) Improving the Quality of Pavement Surface Distress and Transverse Profile Data Collection and Analysis***

Dr. Shelley Stoffels – Penn State

Andy Mergenmeier – FHWA

Dennis Dvorak – FHWA

***Metropolitan Transportation Commission (MTC) San Francisco Bay Area***

Mr. Sui Tan – MTC

# Introduction

- Calibration and Validation
  - Calibrate to what?
  - How?
- Goals
  - Accuracy
  - Consistency
- Calibration is achieved by comparing to reference measures
- Understand the variability in the data

# Options for Determining Ground Reference

- Manual Surveys – Lane Closed to Traffic
- Manual Surveys – From Edge of Pavement
- Windshield Surveys
- Manual Ratings – From Digital Images
- Semi-Automated Ratings – From Digital Images

**Location details and lane markings are critical!**

# Quick Summary of Ground Reference Variability Over the Years

- Manual Surveys – LTPP Study, Rada, et al, 1999
- Manual Surveys – QES staff, PCI Surveys, 2013-2019
- Manual Surveys – State A, 2018
- Manual Windshield Surveys – State B, PCC, June 2019

# Accuracy and Precision for LTPP Manual Ratings

## AC Pavements

| Distress Type | Unit | Distress Severity | Pooled Reference | Group Statistics | | | |
|---|---|---|---|---|---|---|---|
| | | | | Mean | Std. Dev. | COV (%) | Bias |
| Fatigue Cracking | Sq. meters | All Levels (Total) | 14.2 | 16.5 | 6.2 | 38 | 2.3 |
| Longitudinal Cracking WP | meters | All Levels (Total) | 18.4 | 18.3 | 6.0 | 33 | -0.2 |
| Longitudinal Cracking NWP | meters | All Levels (Total) | 75.0 | 70.7 | 14.7 | 21 | -4.3 |
| Transverse Cracking | number | All Levels (Total) | 26.4 | 24.7 | 3.2 | 13 | -1.7 |
| Transverse Cracking | meters | All Levels (Total) | 44.3 | 44.6 | 4.2 | 9 | 0.3 |

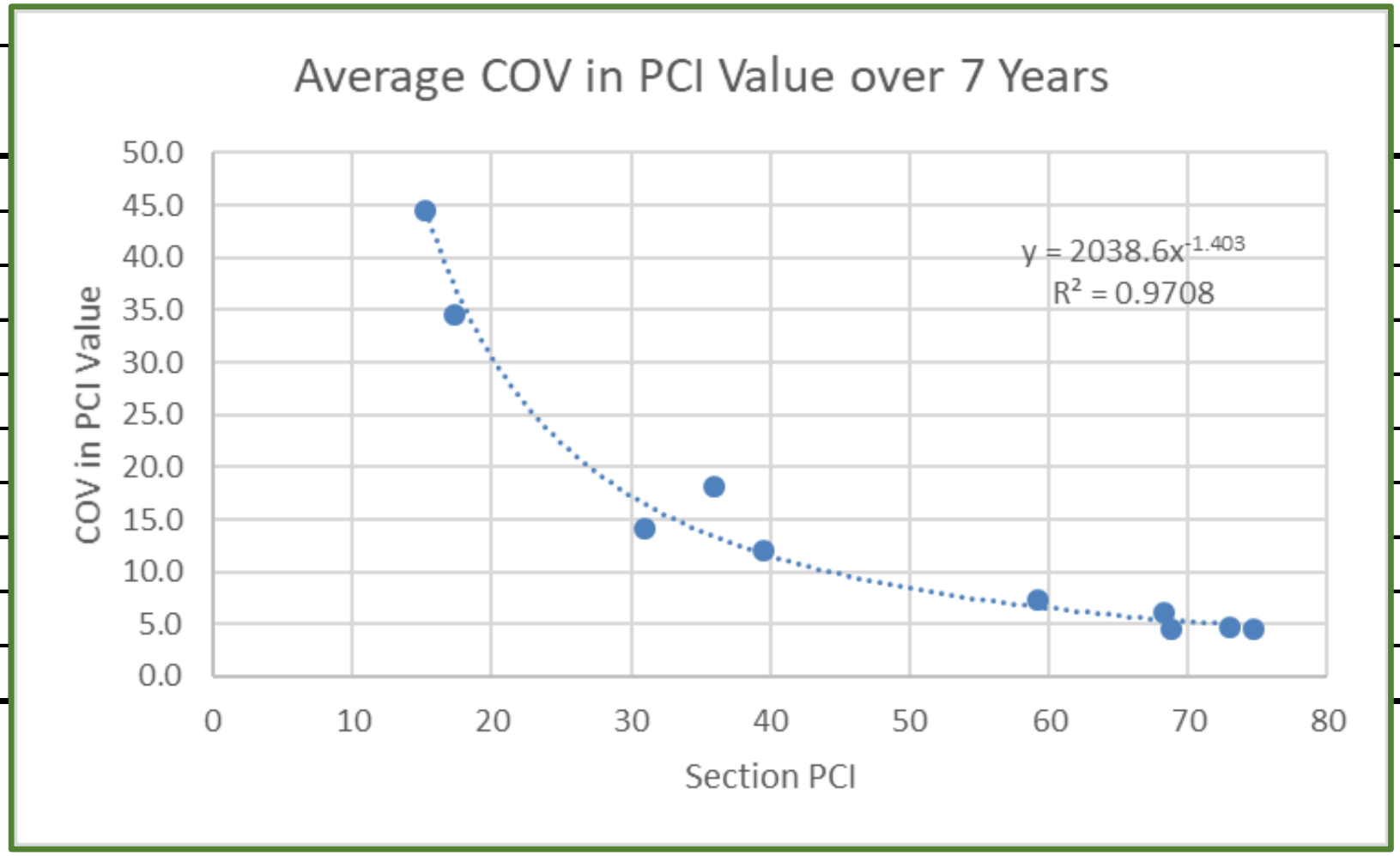
*(Rada, et al., 1999)*

## PCC Pavements

| Distress Type | Unit | Distress Severity | Pooled Reference | Group Statistics | | | |
|---|---|---|---|---|---|---|---|
| | | | | Mean | Std. Dev. | COV (%) | Bias |
| Corner Breaks | number | All Levels (Total) | 3.9 | 3.7 | 0.5 | 14 | -0.2 |
| Longitudinal Cracking | meters | All Levels (Total) | 7.5 | 7.0 | 1.6 | 22 | -0.5 |
| Transverse Cracking | number | All Levels (Total) | 9.4 | 9.6 | 1.4 | 15 | 0.2 |
| Transverse Cracking | meters | All Levels (Total) | 24.8 | 25.0 | 2.1 | 8 | 0.2 |
| Spalling of Long. Joints | meters | All Levels (Total) | 6.6 | 7.2 | 4.9 | 68 | 0.5 |
| Spalling of Trans. Joints | number | All Levels (Total) | 3.7 | 3.4 | 0.9 | 25 | -0.3 |
| Spalling of Trans. Joints | meters | All Levels (Total) | 1.7 | 2.0 | 1.4 | 71 | 0.3 |

# QES Staff PCI Surveys on AC pavements

| Site # | Average All Years |
|---|---|
| 1 | 4.5 |
| 2 | 34.5 |
| 3 | 7.3 |
| 4 | 4.5 |
| 5 | 14.1 |
| 6 | 4.7 |
| 7 | 18.1 |
| 8 | 12.0 |
| 9 | 6.1 |
| 10 | 44.5 |



# State A Cracking Surveys

**Absolute Difference between Reference Rater and Evaluator Rater**

| Distress Type | Trans 1 | Trans 2 | Trans 3 | Trans Total |
|---|---|---|---|---|
| Average % Cracking Difference | 0.2 | 0.8 | 0.1 | 0.3 |
| Maximum % Cracking Difference | 0.9 | 5.7 | 0.7 | 1.5 |
| | | | | |
| Distress Type | WP 1 | WP 2 | WP 3 | WP Total |
| Average % Cracking Difference | 0.4 | 5.9 | 0.4 | 0.3 |
| Maximum % Cracking Difference | 1.3 | 50.4 | 2.7 | 1.3 |
| | | | | |
| Distress Type | NWP 1 | NWP 2 | NWP 3 | NWP Total |
| Average % Cracking Difference | 0.4 | 8.4 | 0.0 | 0.3 |
| Maximum % Cracking Difference | 0.8 | 79.5 | 0.0 | 0.8 |

10 control sites, each 0.3 miles long
Two experienced raters:  Reference Rater, Evaluator Rater

# State B PCC Surveys

**Overall Agreement Among Raters in Windshield Survey of PCC Pavements**

| Distress Type | Agreement Among Raters in Total Distress Amount (All Severities), 100 - COV (%) | Percentage of Ratings more than one STD away from AVG (outliers) |
|---|---|---|
| Transverse Cracking | 82% | 25% |
| Longitudinal Cracking | 82% | 28% |
| Spalling | 64% | 30% |
| Corner Cracking | 56% | 22% |
| Shattered Slabs | 71% | 26% |
| Patching | 74% | 33% |
| Surface Deterioration | 52% | 45% |

# MTC Current Certification for Manual Raters

- Approximately 24 Sites (each site is 100’x width of pavement)
  - 20 Asphalt Concrete Pavement
  - 4 Jointed Concrete Pavement
- Reference values determined by a consensus evaluation (Staff from Chico State University), PCI is calculated
- Each rater completes an independent evaluation on all sites
  - Greater than 50% of the sections must have a PCI within 8 points of the reference PCI
  - No more than 12% of the sections can have a PCI difference greater than 18

# MTC Current Certification for Automated Systems

- Approximately 24 Sites (each site is 200’ x 12’ wheel path)
  - 20 Asphalt Concrete Pavement
  - 4 Jointed Concrete Pavement
- Reference values determined by a consensus evaluation (Staff from Chico State University), PCI is calculated
- Each system completes an independent evaluation on all sites
  - Greater than 50% of the sections must have a PCI within 5 points of the reference PCI
  - No more than 12% of the sections can have a PCI difference greater than 15

# Summary of PCIs from Mar 2018 Rater Certification Field Exam

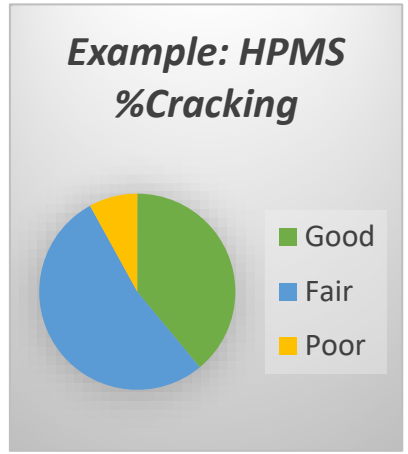
| SECTION ID | G. TRUTH | Rater 1 | Rater 2 | Rater 3 | Rater 4 | Rater 5 | Rater 6 | Rater 7 | Rater 8 | Rater 9 | Rater 10 | Rater 11 | Rater 12 | Rater 13 | Rater 14 | Rater 22 | Rater 23 | Average | AVERAGE MINUS GR. TRUTH | SD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A-1 | 13 | 21 | 11 | 10 | 14 | 14 | 13 | 28 | 24 | 22 | 12 | 33 | 31 | 9 | 21 | 34 | 26 | 17 | -4 | 7 |
| A-2 | 17 | 22 | 23 | 14 | 13 | 29 | 41 | 24 | 21 | 22 | 29 | 47 | 36 | 29 | 41 | 30 | 35 | 23 | -6 | 9 |
| A-3 | 62 | 66 | 60 | 66 | 60 | 62 | 69 | 71 | 68 | 67 | 53 | 72 | 72 | 59 | 60 | 67 | 94 | 65 | -3 | 4 |
| A-4 | 86 | 100 | 82 | 89 | 94 | 86 | 95 | 86 | 93 | 91 | 66 | 80 | 86 | 85 | 76 | 79 | 95 | 91 | -5 | 6 |
| A-5 | 32 | 56 | 42 | 41 | 44 | 51 | 46 | 58 | 49 | 25 | 36 | 52 | 59 | 42 | 49 | 44 | 49 | 48 | -16 | 6 |
| A-6 | 23 | 25 | 27 | 12 | 27 | 26 | 25 | 39 | 26 | 24 | 17 | 32 | 29 | 25 | 29 | 29 | 18 | 26 | -3 | 7 |
| A-7 | 13 | 36 | 12 | 24 | 17 | 20 | 28 | 19 | 32 | 22 | 16 | 36 | 38 | 18 | 32 | 35 | 18 | 24 | -11 | 8 |
| A-8 | 55 | 60 | 47 | 45 | 45 | 44 | 64 | 65 | 61 | 54 | 41 | 49 | 56 | 32 | 44 | 42 | 44 | 54 | 1 | 9 |
| A-9 | 32 | 44 | 36 | 24 | 38 | 44 | 55 | 40 | 43 | 38 | 32 | 41 | 57 | 27 | 41 | 50 | 37 | 41 | -9 | 9 |
| A-10 | 47 | 53 | 52 | 46 | 51 | 61 | 52 | 64 | 63 | 41 | 56 | 31 | 59 | 96 | 47 | 56 | 61 | 55 | -8 | 7 |
| A-11 | 25 | 17 | 20 | 30 | 22 | 32 | 46 | 40 | 34 | 15 | 30 | 29 | 39 | 29 | 35 | 51 | 30 | 30 | -5 | 10 |
| A-12 | 17 | 42 | 32 | 20 | 32 | 23 | 21 | 18 | 43 | 21 | 20 | 40 | 43 | 22 | 38 | 34 | 25 | 29 | -12 | 10 |
| A-13 | 51 | 52 | 52 | 52 | 63 | 65 | 61 | 63 | 48 | 49 | 54 | 70 | 65 | 63 | 56 | 67 | 46 | 57 | -6 | 7 |
| A-14 | 61 | 55 | 61 | 59 | 61 | 63 | 65 | 62 | 63 | 54 | 63 | 64 | 60 | 47 | 44 | 53 | 42 | 61 | 0 | 3 |
| A-15 | 20 | 52 | 43 | 45 | 32 | 55 | 59 | 49 | 50 | 44 | 39 | 69 | 63 | 41 | 60 | 59 | 59 | 48 | -28 | 8 |
| A-16 | 71 | 85 | 69 | 63 | 69 | 70 | 66 | 70 | 64 | 60 | 56 | 65 | 73 | 63 | 65 | 68 | 67 | 70 | 2 | 7 |
| A-17 | 46 | 75 | 35 | 51 | 45 | 63 | 55 | 51 | 50 | 47 | 54 | 38 | 49 | 44 | 39 | 40 | 42 | 53 | -7 | 12 |
| A-18 | 49 | 74 | 45 | 34 | 43 | 49 | 26 | 58 | 61 | 23 | 41 | 46 | 57 | 32 | 43 | 37 | 63 | 49 | 0 | 15 |
| A-19 | 48 | 52 | 54 | 36 | 53 | 44 | 26 | 68 | 56 | 44 | 43 | 51 | 55 | 33 | 31 | 26 | 64 | 49 | -1 | 13 |
| A-23 | 94 | 100 | 97 | 96 | 95 | 96 | 100 | 73 | 97 | 100 | 98 | 97 | 97 | 96 | 79 | 95 | 93 | 94 | 0 | 9 |
| P-1 | 59 | 73 | 29 | 56 | 27 | 65 | 59 | 60 | 66 | 44 | 63 | 62 | 54 | 63 | 85 | 83 | 72 | 54 | 5 | 17 |
| P-3 | 53 | 61 | 23 | 45 | 30 | 59 | 56 | 50 | 44 | 46 | 63 | 42 | 60 | 63 | 58 | 46 | 51 | 46 | 7 | 14 |
| P-4 | 74 | 81 | 54 | 74 | 54 | 86 | 94 | 80 | 70 | 78 | 84 | 74 | 86 | 86 | 76 | 82 | 76 | 74 | 0 | 14 |
| P-6 | 47 | 51 | 30 | 50 | 28 | 53 | 63 | 54 | 46 | 40 | 58 | 56 | 66 | 52 | 73 | 52 | 57 | 47 | 0 | 12 |
| Average | 53 | 57 | 46 | 37 | 36 | 43 | 44 | 44 | 44 | 38 | 40 | 46 | 50 | 41 | 44 | 45 | 45 | | | |
| No. Meeting 1st Criterion | | 14 | 16 | 17 | 15 | 15 | 11 | 12 | 14 | 17 | 14 | 10 | 11 | 13 | 10 | 10 | 11 | | | |
| % Meeting 1st Criterion | | 58% | 67% | 71% | 63% | 63% | 46% | 0.5 | 0.583333333 | 71% | 58% | 42% | 46% | 54% | 42% | 42% | 46% | | | |
| No. Not Meeting 2nd Criterion | | 6 | 4 | 1 | 4 | 2 | 7 | 4 | 3 | 2 | 2 | 7 | 7 | 3 | 6 | 6 | 3 | | | |
| % Not Meeting 2nd Criterion | | 25% | 17% | 4% | 17% | 8% | 29% | 17% | 13% | 8% | 8% | 29% | 29% | 13% | 25% | 25% | 13% | | | |
| Meets All Criteria | | NO | OK | OK | OK | OK | NO | OK | OK | OK | OK | NO | NO | OK | NO | NO | NO | | | |

| | | | |
|---|---|---|---|
| 1st Threshold | +/- | 8 | PCI |
| 2nd Threshold | +/- | 18 | PCI |

# Imaging System Recommended Guidelines – Step 1

- Agency selects control sites
  - Recommended minimum length of 0.3 miles (1,584’)
- Sites should be chosen to represent the agency’s
  - Pavement types
  - Surface textures
  - Frequently-occurring distress conditions

    *Example: Sections with HPMS %Cracking Good, Fair and Poor*
  - Distresses of high concern and impact in the decision-making process
- Minimum of six sites is recommended, but each is statistically evaluated independently



# Imaging System Recommended Guidelines – Step 1

- Agency performs manual cracking distress ratings under closed traffic lanes
  - Sections and rating intervals must be clearly marked: Start, End and Intermediate Pts
    - Rating intervals of minimum length 0.03 miles (158.4’)
    - Control sections should have minimum of 10 rating intervals
  - Replicate ratings are recommended for determination of the ground reference
    - Equivalence of ratings should be assessed
    - Single rating or consensus used as reference
    - Replicates should not be averaged
  - Mark or use template to identify wheel paths, following HPMS directives
  - Develop summarized cracking distresses at 0.03-mile intervals
    - HPMS directives
    - Agency definitions

**Subsections for control site surveys must be clearly marked**

# This state agency uses a template for manual ground reference surveys

# Imaging System Recommended Guidelines – Step 2

- Vendors collect digital images over all control sites
- Vendors submit images, viewing, and manual rating software
- Vendors submit cracking distress summaries at 0.03-mile increments
  - Important that the increments match the pavement markings used for the ground reference ratings
- Agency may choose to view and/or perform independent ratings from the images

# Imaging System Recommended Guidelines – Step 3

- Agency completes a statistical evaluation of the submitted data
  - Equivalence Test with Paired Data
  - Determines a pass/fail for each control site
- Agency should identify pass/fail criteria before data is evaluated
- Agency may weight some control sites differently than others
  - Key distresses
  - Fine cracking
  - Pavement type

# Equivalence Testing with Paired Data

- Hypothesis tests are typically used to look for a **difference** in the results large enough to affect the outcome

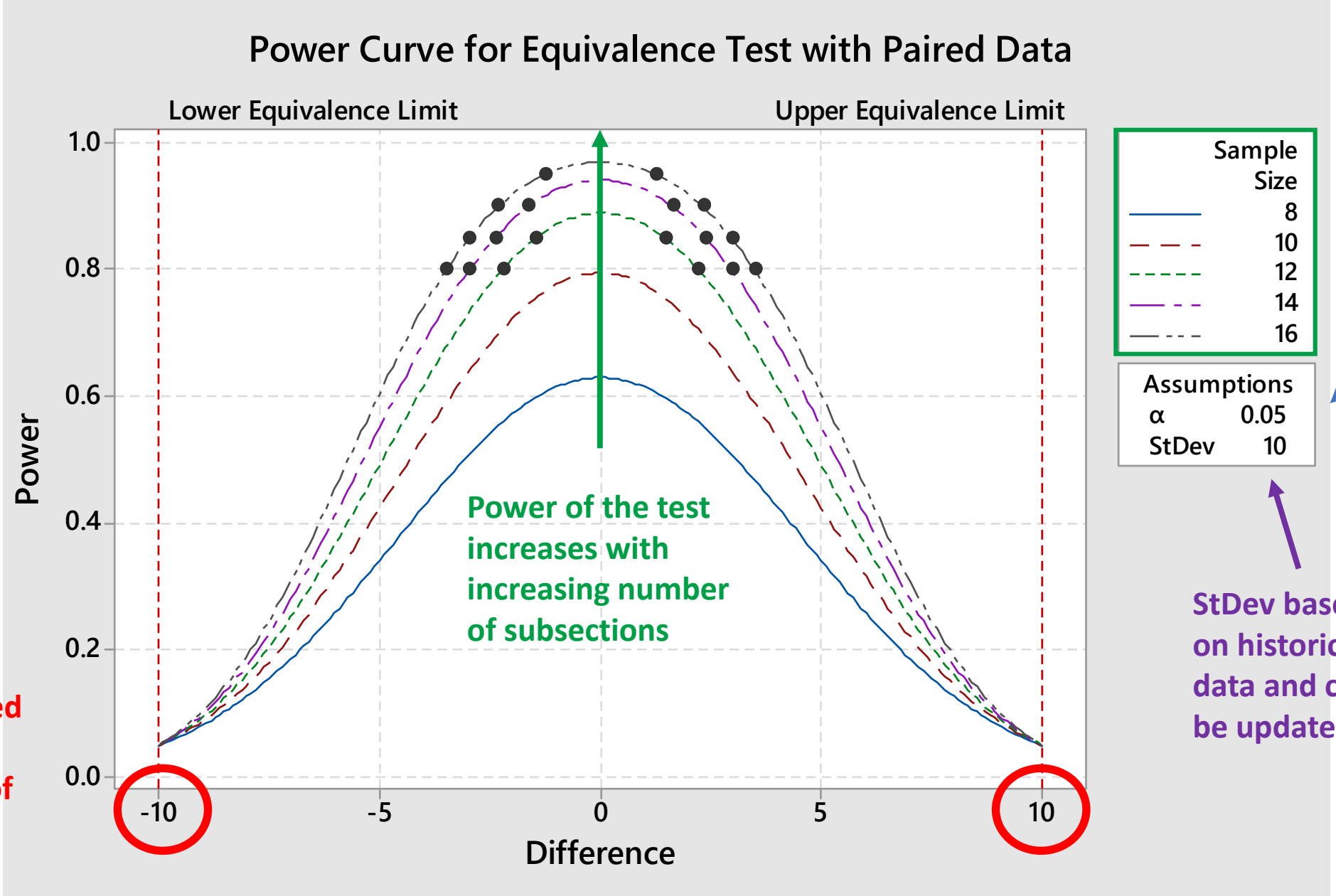
  ***Example:*** *Does the treatment significantly improve the condition?*

- Goal is to identify vendors or equipment that give the **same** results as the ground reference or results close enough to **not** affect the outcomes
- Equivalence tests are hypothesis tests formulated for when **equivalence** rather than **significant difference** is the goal
- Using a **paired t-test** for the equivalence testing, with the ratings carefully paired on the same rating subsections, offsets the variability in the pavement along the length of the control sites

# Equivalence Testing with Paired Data

- In equivalence testing, **α (alpha) is the risk level of accepting a method as equivalent when it is not**
- β (beta) is the risk level of rejecting equivalence when the data is in fact equivalent
- **Power** (1-β) **is the likelihood of correctly concluding that the difference is within the equivalence limits, when this is true**
- N is the number of subsections; more subsections reduce risks and increases the power of the test
- The upper and lower limits should be set at the differences that would have a meaningful impact on the outcomes

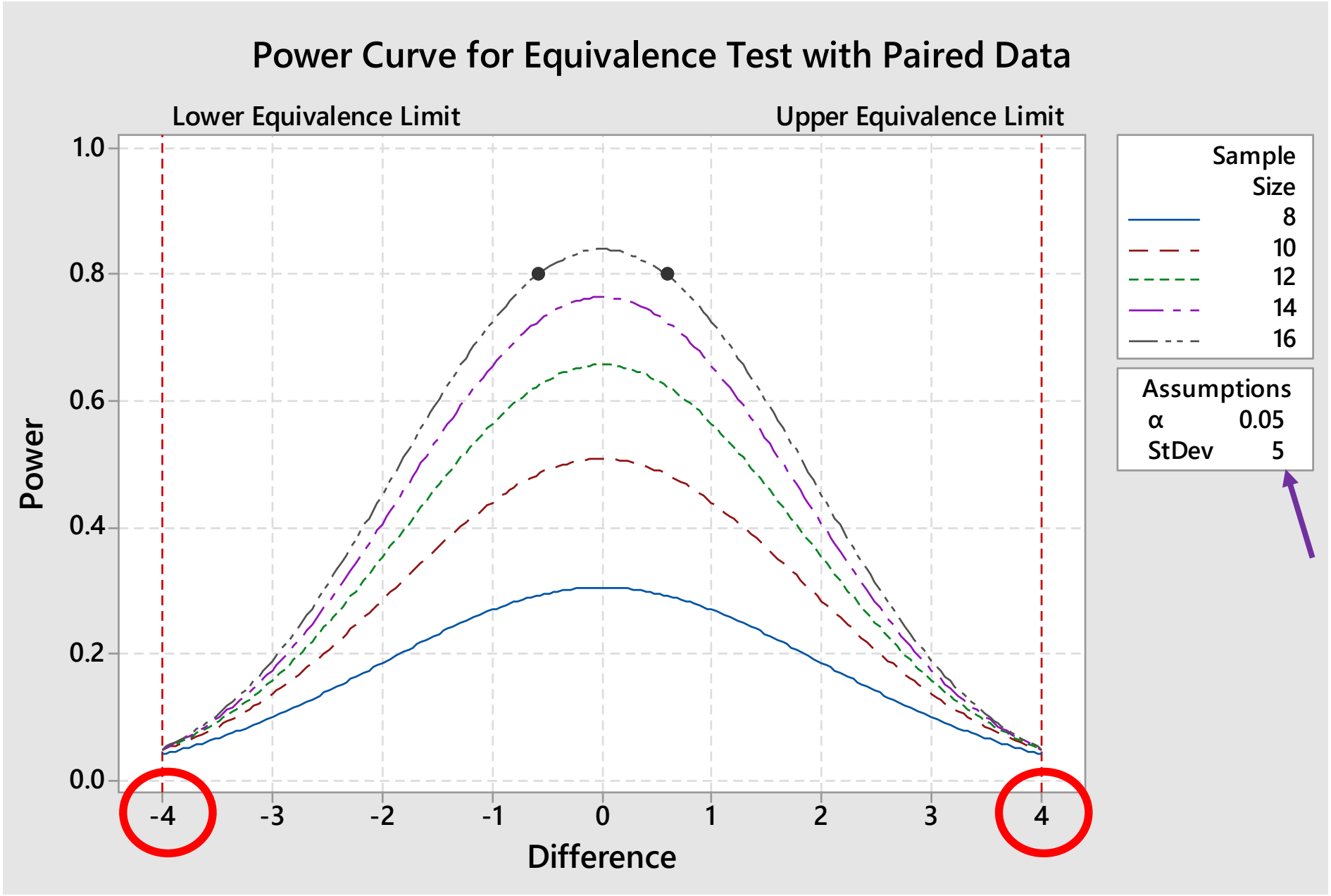
Power is the likelihood of correctly concluding that the difference is within the equivalence limits




α is the agency's risk of accepting a vendor as equivalent when it is not

StDev based on historical data and can be updated

Limits are based upon the intended use of the data


Power Curve for Equivalence Test with Paired Data
Lower Equivalence Limit
Upper Equivalence Limit
1.0
0.8
0.6
0.4
0.2
0.0
Power
-4
-3
-2
-1
0
1
2
3
4
Difference
Sample Size
8
10
12
14
16
Assumptions
α 0.05
StDev 5

# Interpreting the results

- A fictional agency rates 6 control sites of AC and 3 control sites of PCC
- Vendor ratings are compared to the ground reference rating for each site
  - Some sites are found to be equivalent
  - Some sites are not found to be equivalent
- Drawing Conclusions
  - Based on a priority weighting of sections and or pavement types

| Control Site ID | Pavement Type | HPMS % Cracking | Site Weight | Vendor A | Vendor B |
|---|---|---|---|---|---|
| A | AC | Good | 2 | EQ | Not EQ |
| B | AC | Fair | 2 | Not EQ | Not EQ |
| C | AC | Fair | 1 | EQ | EQ |
| D | AC | Fair | 1 | Not EQ | EQ |
| E | AC | Poor | 1 | EQ | EQ |
| F | AC | Poor | 1 | Not EQ | EQ |
| G | PCC | Good | 1 | EQ | EQ |
| H | PCC | Fair | 2 | EQ | EQ |
| I | PCC | Poor | 1 | Not EQ | EQ |
| | | | SCORE | 7 | 8 |

# Practical Guidelines for Calibration and Verification of Airfield Pavement Distress Data

Monty Wade, P.E.

Applied Pavement Technology, Inc.

June 10, 2020

# Outline

- ACRP Research Report 203, *Collecting, Applying, and Maintaining Pavement Condition Data at Airports*
- Comparison of results from automated data collection and manual inspection procedures
- Use of data collection to drive pavement management decisions
- Future of airport pavement data collection and interpretation

# Acknowledgements – ACRP Project Team


- APTech:
  - David Peshkin (PI)
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  - Kyle Potvin
  - Katherine Gauthier
  - Monty Wade
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  - Eric Risner
  - Ryan Robinson
  - Chris Snyder
  - Marianne Cardwell
- PMS Ltd. (Ireland)
  - Kieran Feighan

# Acknowledgements – ACRP Project Panel


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- Owen Silbaugh, Massachusetts DOT
- Dianne Walker, DW LLC
- Kelvin Wang, Oklahoma State University
- Gregory Cline, Al Larkin – FAA Liaisons
- Christine Gerencher, TRB Liaison
- Theresia Schatz, ACRP Senior Program Officer

# ACRP Research Report 203 Objectives

- Present best practice guidelines for airport pavement data
  - Collection
  - Use
  - Maintenance and storage

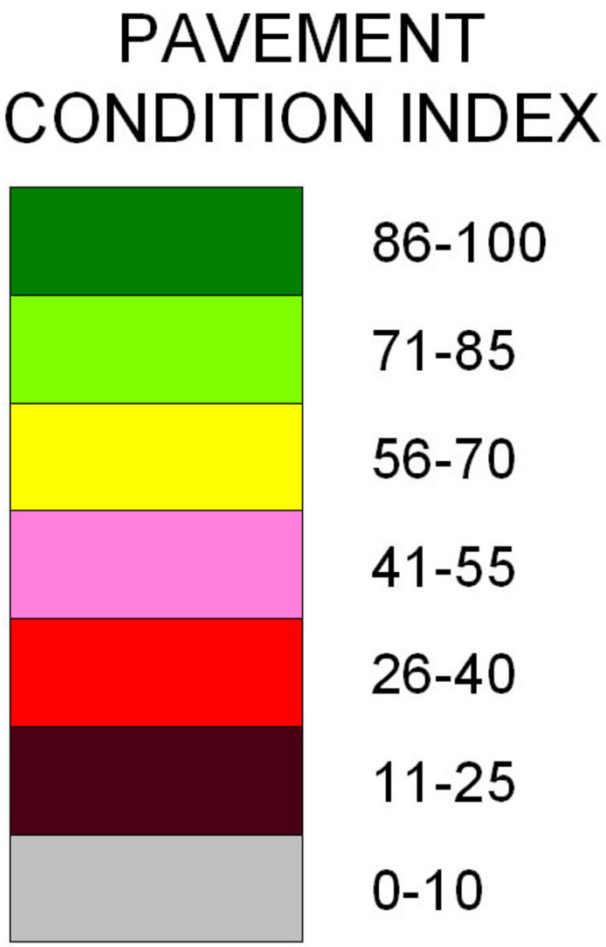
# Types of Pavement Condition Data

- Distress
- Surface characteristics
- Structural condition

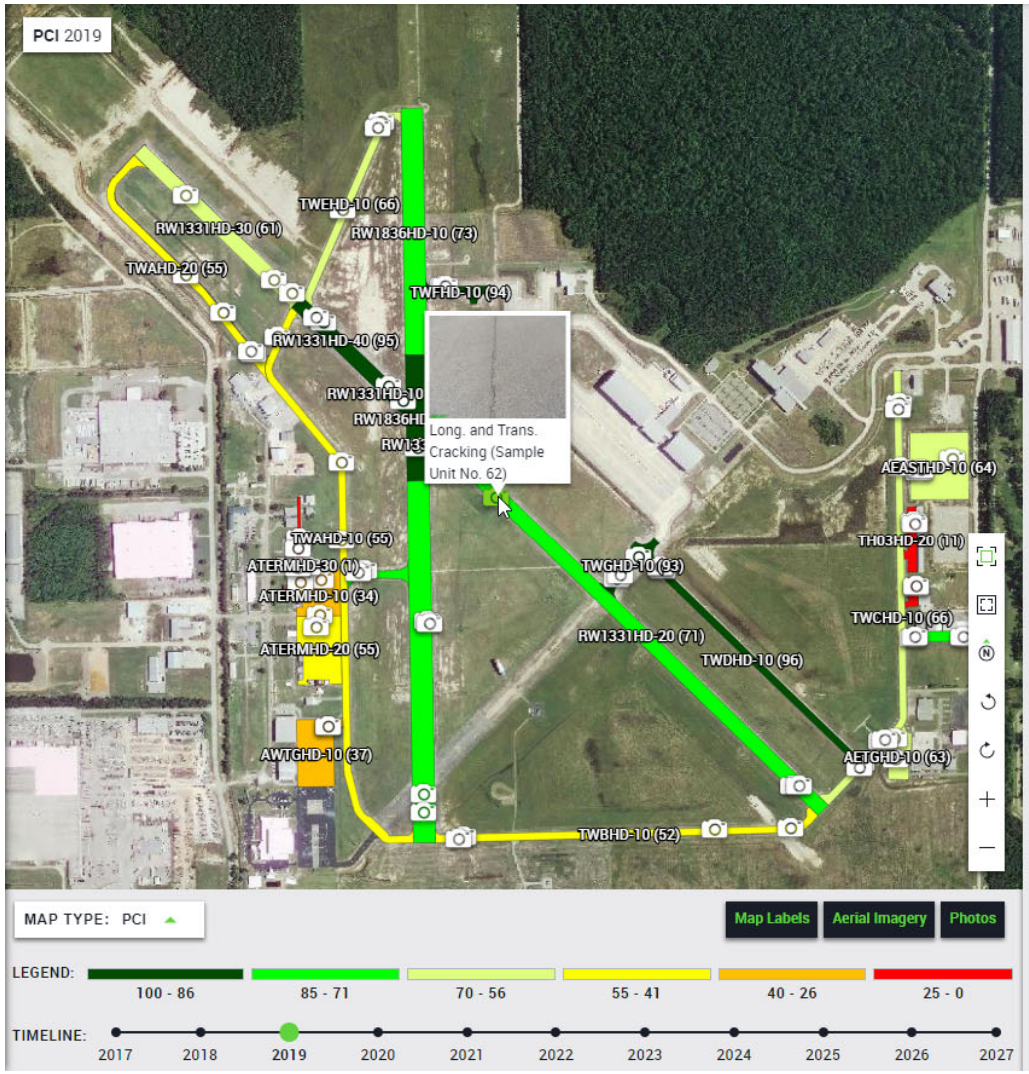
Collection of distress data will be the focus of this presentation.

# Distress Condition Data

- ASTM D5340 has been the traditional standard for airfield pavements
- Results are presented as Pavement Condition Index (PCI)



# Distress Condition Data Presentation




Network / Branch / Section

Inventory | Inspection | Photos | Condition | Recommende

PCI Data | PCI by Year Chart

## PCI Summary by Section

The following table summarizes the section PCIs assuming no work
from actual inspections, while the 2018-2027 PCIs are forecasted val

| Branch ID | Section ID | 2017 | 2018 | 2019 |
|---|---|---|---|---|
| AEASTHD | 10 | 71 | 67 | 64 |
| AETGHD | 10 | 70 | 66 | 63 |
| ATERMHD | 10 | 36 | 35 | 34 |
| ATERMHD | 20 | 57 | 56 | 55 |
| ATERMHD | 30 | 3 | 2 | 1 |
| AWTGHD | 10 | 42 | 40 | 37 |
| RW1331HD | 10 | 100 | 99 | 98 |
| RW1331HD | 20 | 74 | 72 | 71 |
| RW1331HD | 30 | 64 | 62 | 61 |
| RW1331HD | 40 | 98 | 96 | 95 |
| RW1836HD | 10 | 76 | 74 | 73 |
| RW1836HD | 20 | 100 | 99 | 98 |
| TH01HD | 10 | 26 | 25 | 23 |
| TH02HD | 10 | 23 | 22 | 20 |
| TH02HD | 20 | 77 | 76 | 74 |

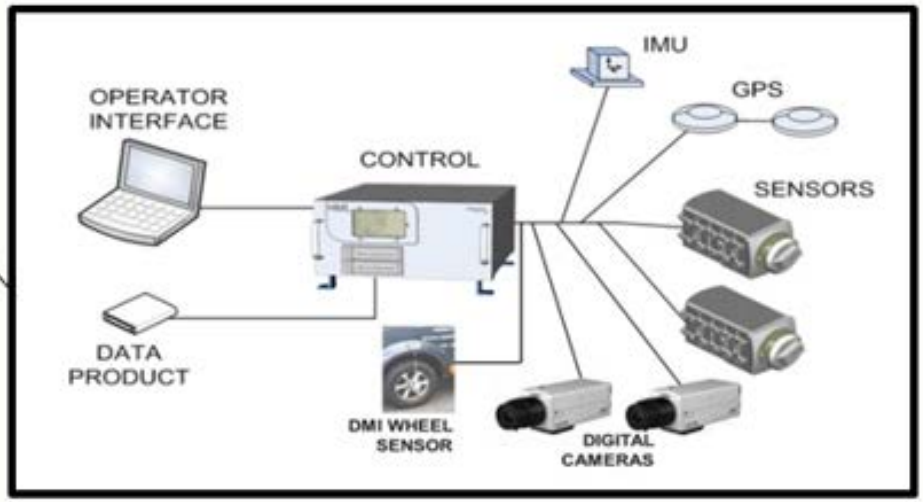
# Distress Data Collection Methods

- Visual (manual) condition survey
- Light Detection and Ranging (LiDAR)
- Two- and three-dimensional (2D and 3D) laser imaging
- Vehicle-mounted camera survey
- Unmanned-mounted camera survey (small unmanned aircraft system or unmanned aerial vehicle [sUAS/UAV])

# LiDAR Data Collection Equipment

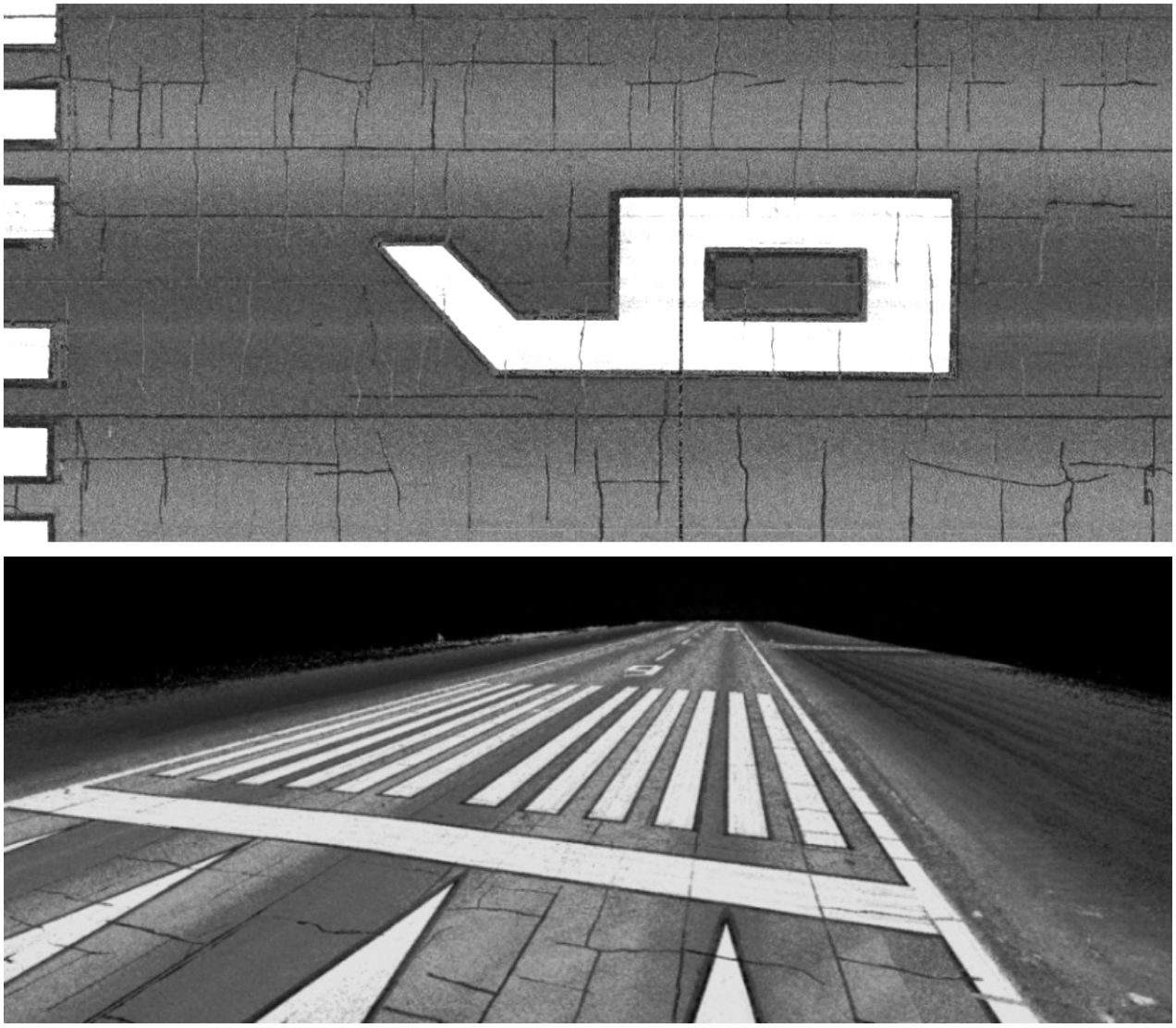
MMS VEHICLE

LiDAR SENSORS AND CAMERAS

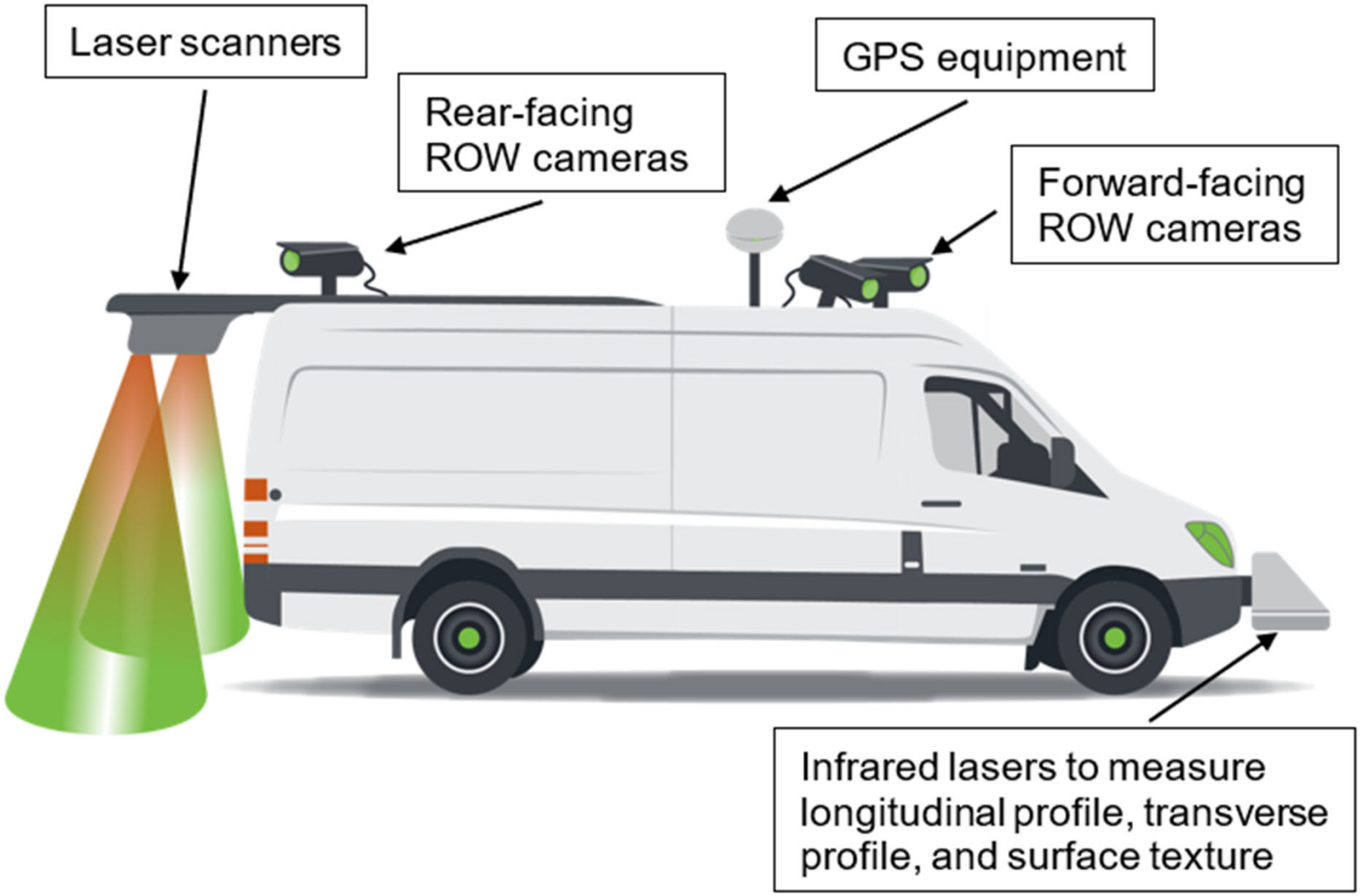



EQUIPMENT

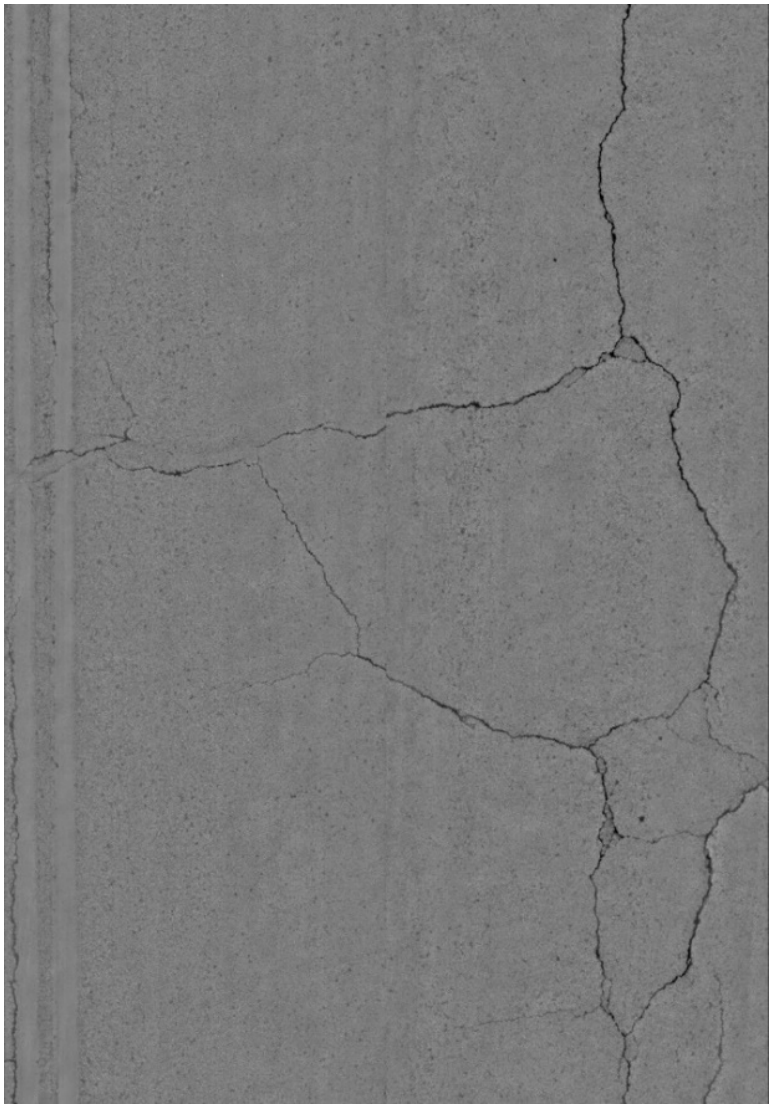
# LiDAR Data Example

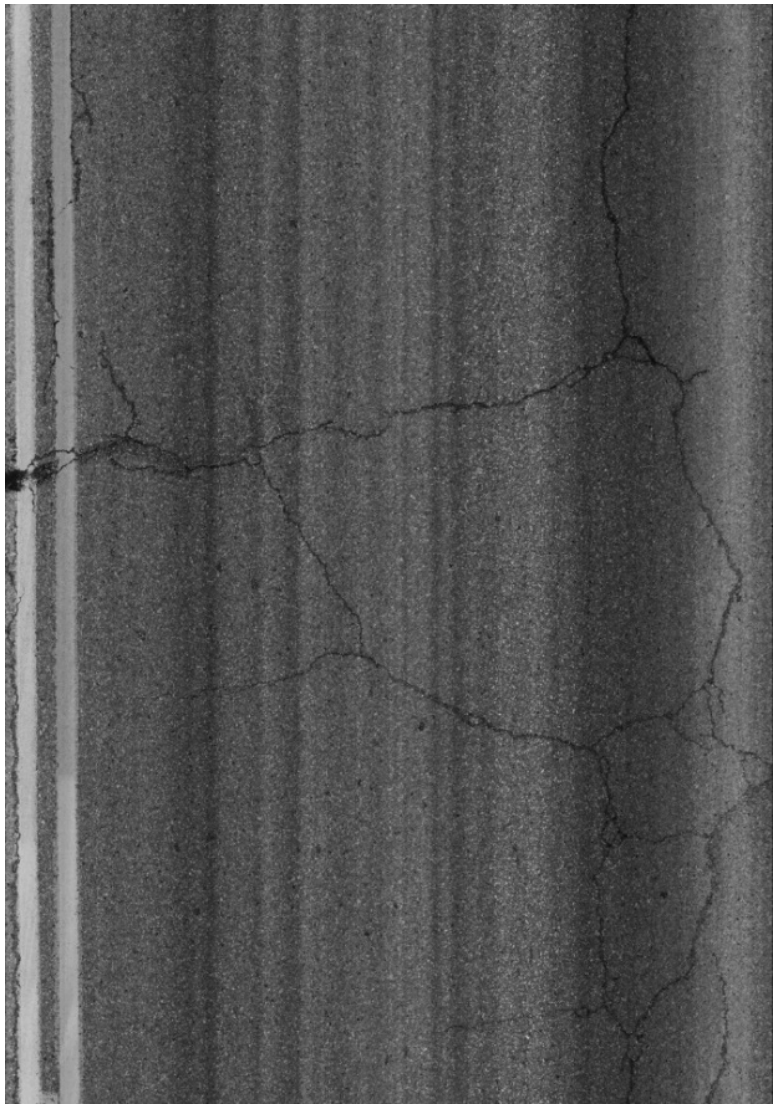


# Laser Imaging Data Collection Equipment

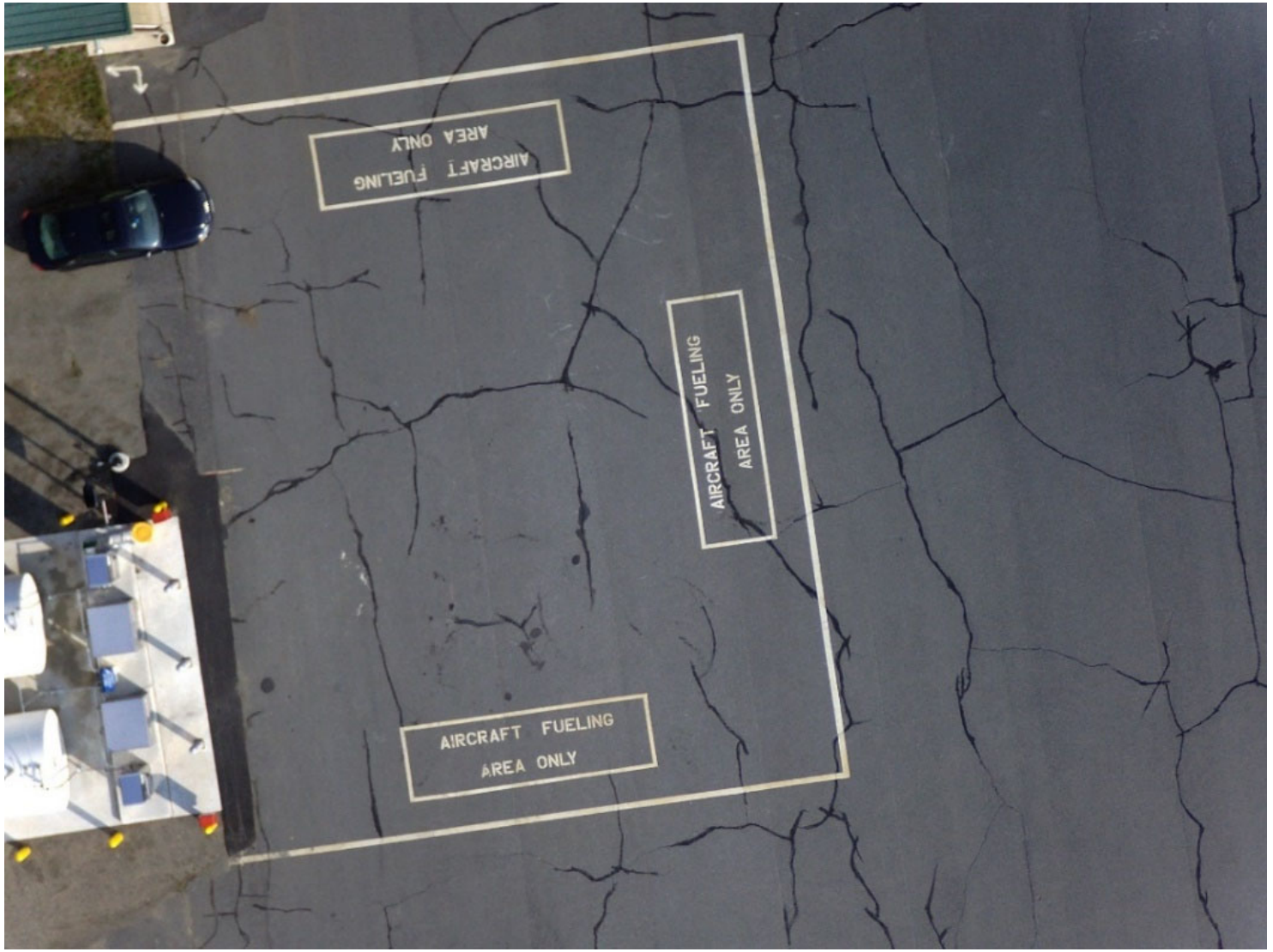


# Laser Imaging Data Example





# sUAS/UAV Data Example



# ASTM D5340 Asphalt Distress Identification (1/2)

| Distress | Manual | Laser Imaging | LiDAR | UAV Imaging |
|---|---|---|---|---|
| Alligator cracking | ☒ Low Severity<br>☒ Medium Severity<br>☒ High Severity | ☒ Low Severity[1]<br>☒ Medium Severity<br>☒ High Severity | ☒ Low Severity[2]<br>☒ Medium Severity<br>☒ High Severity | ☒ Low Severity[2]<br>☒ Medium Severity<br>☒ High Severity |
| Bleeding | ☒ Severity N/A | ☒ Severity N/A[3] | ☐ Severity N/A | ☒ Severity N/A[3] |
| Block cracking | ☒ Low Severity<br>☒ Medium Severity<br>☒ High Severity | ☒ Low Severity[4]<br>☒ Medium Severity[4]<br>☒ High Severity[4] | ☒ Low Severity[2]<br>☒ Medium Severity<br>☒ High Severity | ☒ Low Severity[2]<br>☒ Medium Severity<br>☒ High Severity |
| Corrugation | ☒ Low Severity<br>☒ Medium Severity<br>☒ High Severity | ☐ Low Severity<br>☐ Medium Severity<br>☐ High Severity | ☒ Low Severity<br>☒ Medium Severity<br>☒ High Severity | ☐ Low Severity<br>☐ Medium Severity<br>☐ High Severity |
| Depression | ☒ Low Severity<br>☒ Medium Severity<br>☒ High Severity | ☐ Low Severity<br>☐ Medium Severity<br>☐ High Severity | ☒ Low Severity<br>☒ Medium Severity<br>☒ High Severity | ☐ Low Severity<br>☐ Medium Severity<br>☐ High Severity |
| Jet blast erosion | ☒ Severity N/A | ☐ Severity N/A | ☐ Severity N/A | ☐ Severity N/A |
| Joint reflection cracking | ☒ Low Severity<br>☒ Medium Severity<br>☒ High Severity | ☒ Low Severity<br>☒ Medium Severity<br>☒ High Severity | ☒ Low Severity[2]<br>☒ Medium Severity<br>☒ High Severity | ☒ Low Severity[2]<br>☒ Medium Severity<br>☒ High Severity |
| Longitudinal and transverse cracking | ☒ Low Severity<br>☒ Medium Severity<br>☒ High Severity | ☒ Low Severity<br>☒ Medium Severity<br>☒ High Severity | ☒ Low Severity[2]<br>☒ Medium Severity<br>☒ High Severity | ☒ Low Severity[2]<br>☒ Medium Severity<br>☒ High Severity |
| Oil spillage | ☒ Severity N/A | ☐ Severity N/A | ☐ Severity N/A | ☐ Severity N/A |

[1] Data collection method applicable if wheelpath location is known.
[2] Data collection method applicable only if cracks have been sealed.
[3] Data collection method applicable if bleeding is not scattered and uniformly distributed.
[4] Full extent of block cracking may be difficult to document without image stitching.

# ASTM D5340 Asphalt Distress Identification (2/2)

| Distress | Manual | Laser Imaging | LiDAR | UAV Imaging |
|---|---|---|---|---|
| Patching and utility cut patching | ☒ Low Severity<br>☒ Medium Severity<br>☒ High Severity | ☒ Low Severity<br>☒ Medium Severity<br>☒ High Severity | ☐ Low Severity<br>☐ Medium Severity<br>☒ High Severity | ☒ Low Severity[5]<br>☒ Medium Severity[5]<br>☒ High Severity |
| Polished aggregate | ☒ Severity N/A | ☐ Severity N/A | ☐ Severity N/A | ☐ Severity N/A |
| Raveling | ☒ Low Severity<br>☒ Medium Severity<br>☒ High Severity | ☐ Low Severity<br>☒ Medium Severity<br>☒ High Severity | ☐ Low Severity<br>☒ Medium Severity<br>☒ High Severity | ☐ Low Severity<br>☐ Medium Severity<br>☐ High Severity |
| Rutting | ☒ Low Severity<br>☒ Medium Severity<br>☒ High Severity | ☒ Low Severity<br>☒ Medium Severity<br>☒ High Severity | ☒ Low Severity<br>☒ Medium Severity<br>☒ High Severity | ☐ Low Severity<br>☐ Medium Severity<br>☐ High Severity |
| Shoving | ☒ Low Severity<br>☒ Medium Severity<br>☒ High Severity | ☒ Low Severity<br>☒ Medium Severity<br>☒ High Severity | ☒ Low Severity<br>☒ Medium Severity<br>☒ High Severity | ☐ Low Severity<br>☒ Medium Severity<br>☒ High Severity |
| Slippage cracking | ☒ Severity N/A | ☒ Severity N/A | ☒ Severity N/A | ☒ Severity N/A |
| Swelling | ☒ Low Severity<br>☒ Medium Severity<br>☒ High Severity | ☐ Low Severity<br>☐ Medium Severity<br>☐ High Severity | ☒ Low Severity<br>☒ Medium Severity<br>☒ High Severity | ☐ Low Severity<br>☒ Medium Severity<br>☒ High Severity |
| Weathering | ☒ Low Severity<br>☒ Medium Severity<br>☒ High Severity | ☐ Low Severity<br>☐ Medium Severity<br>☐ High Severity | ☐ Low Severity<br>☐ Medium Severity<br>☐ High Severity | ☐ Low Severity<br>☐ Medium Severity<br>☐ High Severity |

[5] Data collection method applicable where there are color differences between patch material and original asphalt.

# ASTM D5340 Concrete Distress Identification (1/2)

| Distress | Manual | Laser Imaging | LiDAR | UAV Imaging |
|---|---|---|---|---|
| Blowup | ☒ Low Severity<br>☒ Medium Severity<br>☒ High Severity | ☒ Low Severity<br>☒ Medium Severity<br>☒ High Severity | ☒ Low Severity<br>☒ Medium Severity<br>☒ High Severity | ☒ Low Severity<br>☒ Medium Severity<br>☒ High Severity |
| Corner breaks | ☒ Low Severity<br>☒ Medium Severity<br>☒ High Severity | ☒ Low Severity<br>☒ Medium Severity<br>☒ High Severity | ☒ Low Severity[1]<br>☒ Medium Severity<br>☒ High Severity | ☒ Low Severity[1]<br>☒ Medium Severity[1]<br>☒ High Severity |
| Longitudinal, transverse, and diagonal cracks | ☒ Low Severity<br>☒ Medium Severity<br>☒ High Severity | ☒ Low Severity<br>☒ Medium Severity<br>☒ High Severity | ☒ Low Severity[1]<br>☒ Medium Severity<br>☐ High Severity | ☒ Low Severity[1]<br>☒ Medium Severity[1]<br>☒ High Severity |
| Durability cracking | ☒ Low Severity<br>☒ Medium Severity<br>☒ High Severity | ☐ Low Severity<br>☒ Medium Severity<br>☒ High Severity | ☐ Low Severity<br>☐ Medium Severity<br>☒ High Severity | ☐ Low Severity<br>☐ Medium Severity<br>☐ High Severity |
| Joint seal damage | ☒ Low Severity<br>☒ Medium Severity<br>☒ High Severity | ☒ Low Severity[2]<br>☒ Medium Severity[2]<br>☒ High Severity[2] | ☒ Low Severity[2]<br>☒ Medium Severity[2]<br>☒ High Severity[2] | ☒ Low Severity[2]<br>☒ Medium Severity[2]<br>☒ High Severity[2] |
| Patching | ☒ Low Severity<br>☒ Medium Severity<br>☒ High Severity | ☒ Low Severity<br>☒ Medium Severity<br>☒ High Severity | ☐ Low Severity<br>☐ Medium Severity<br>☒ High Severity | ☒ Low Severity[3]<br>☒ Medium Severity[3]<br>☒ High Severity |

[1] Data collection method applicable only if cracks have been sealed.

[2] Data collection method applicable if damage is from extrusion, vegetation growth, or sliver spalls.

[3] Data collection method applicable depending where there are color differences between patch material and original concrete.

# ASTM D5340 Concrete Distress Identification (2/2)

| Distress | Manual | Laser Imaging | LiDAR | UAV Imaging |
|---|---|---|---|---|
| Popouts | ☒ Severity N/A | ☒ Severity N/A | ☐ Severity N/A | ☐ Severity N/A |
| Pumping | ☒ Severity N/A | ☒ Severity N/A[4] | ☒ Severity N/A[4] | ☒ Severity N/A[4] |
| Scaling | ☒ Low Severity<br>☒ Medium Severity<br>☒ High Severity | ☐ Low Severity<br>☒ Medium Severity<br>☒ High Severity | ☐ Low Severity<br>☐ Medium Severity<br>☒ High Severity | ☐ Low Severity<br>☐ Medium Severity<br>☒ High Severity |
| Settlement | ☒ Low Severity<br>☒ Medium Severity<br>☒ High Severity | ☒ Low Severity<br>☒ Medium Severity<br>☒ High Severity | ☐ Low Severity<br>☐ Medium Severity<br>☒ High Severity | ☐ Low Severity<br>☐ Medium Severity<br>☒ High Severity |
| Shattered slab | ☒ Low Severity<br>☒ Medium Severity<br>☒ High Severity | ☒ Low Severity<br>☒ Medium Severity<br>☒ High Severity | ☒ Low Severity<br>☒ Medium Severity<br>☒ High Severity | ☒ Low Severity[1]<br>☒ Medium Severity[1]<br>☒ High Severity |
| Shrinkage cracking | ☒ Severity N/A | ☒ Severity N/A[5] | ☐ Severity N/A | ☐ Severity N/A |
| Spalling | ☒ Low Severity<br>☒ Medium Severity<br>☒ High Severity | ☒ Low Severity<br>☒ Medium Severity<br>☒ High Severity | ☒ Low Severity[1]<br>☒ Medium Severity<br>☒ High Severity | ☒ Low Severity[1]<br>☒ Medium Severity[1]<br>☒ High Severity |
| Alkali-silica reaction (ASR) | ☒ Low Severity<br>☒ Medium Severity<br>☒ High Severity | ☐ Low Severity<br>☒ Medium Severity<br>☒ High Severity | ☐ Low Severity<br>☐ Medium Severity<br>☒ High Severity | ☐ Low Severity<br>☐ Medium Severity<br>☒ High Severity |

[1] Data collection method applicable only if cracks have been sealed.

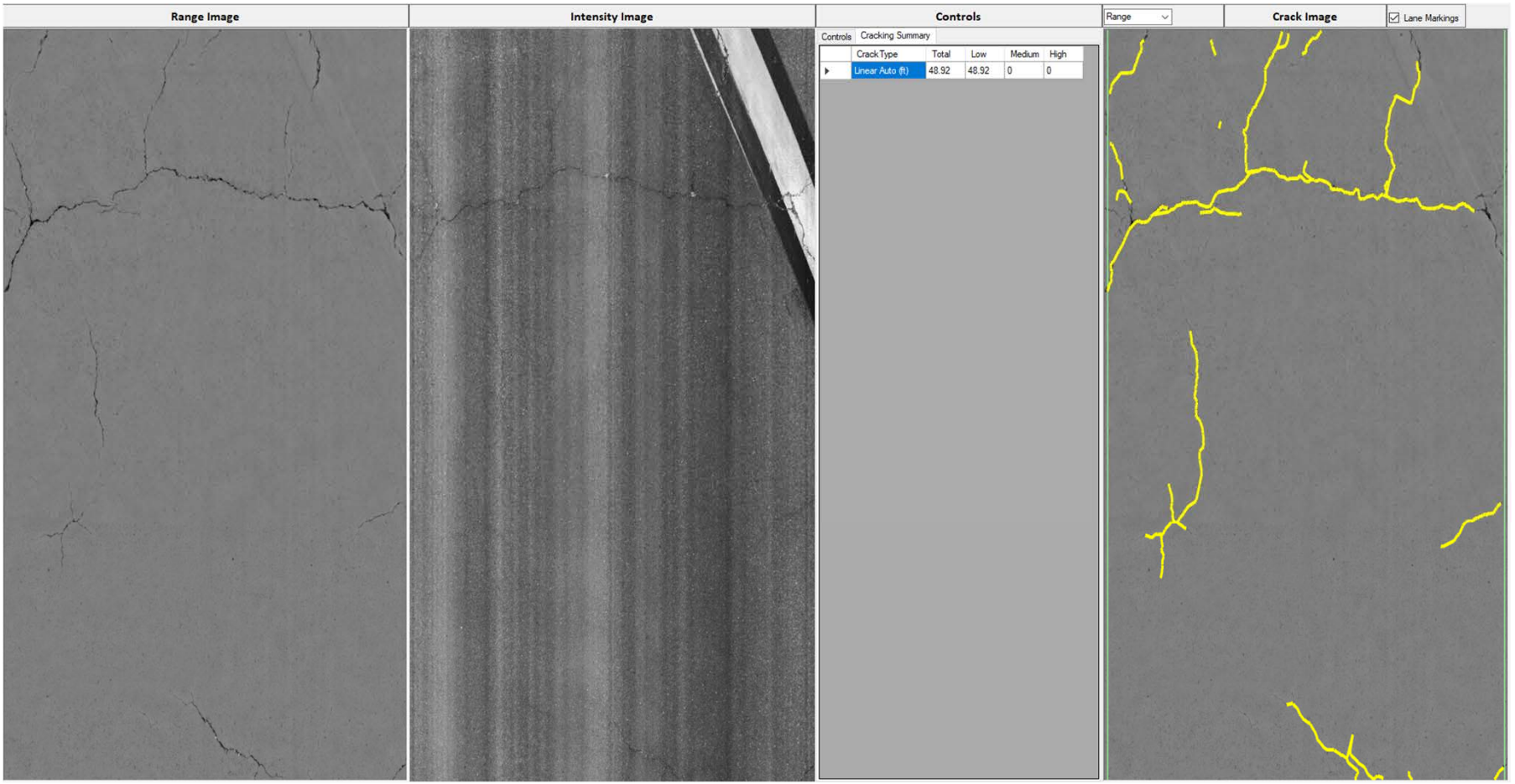
[4] Data collection method applicable depending on extent of pumping.

[5] Data collection method applicable depending on characteristic of shrinkage cracking.

# Automated vs. Manual Collection

- Manual inspection can be an operations burden for busy airfields
- Can automated pavement data collection be beneficial on airfield pavements?
- Do you need to identify all distresses in accordance with ASTM D5340?

# Automated Distress Detection

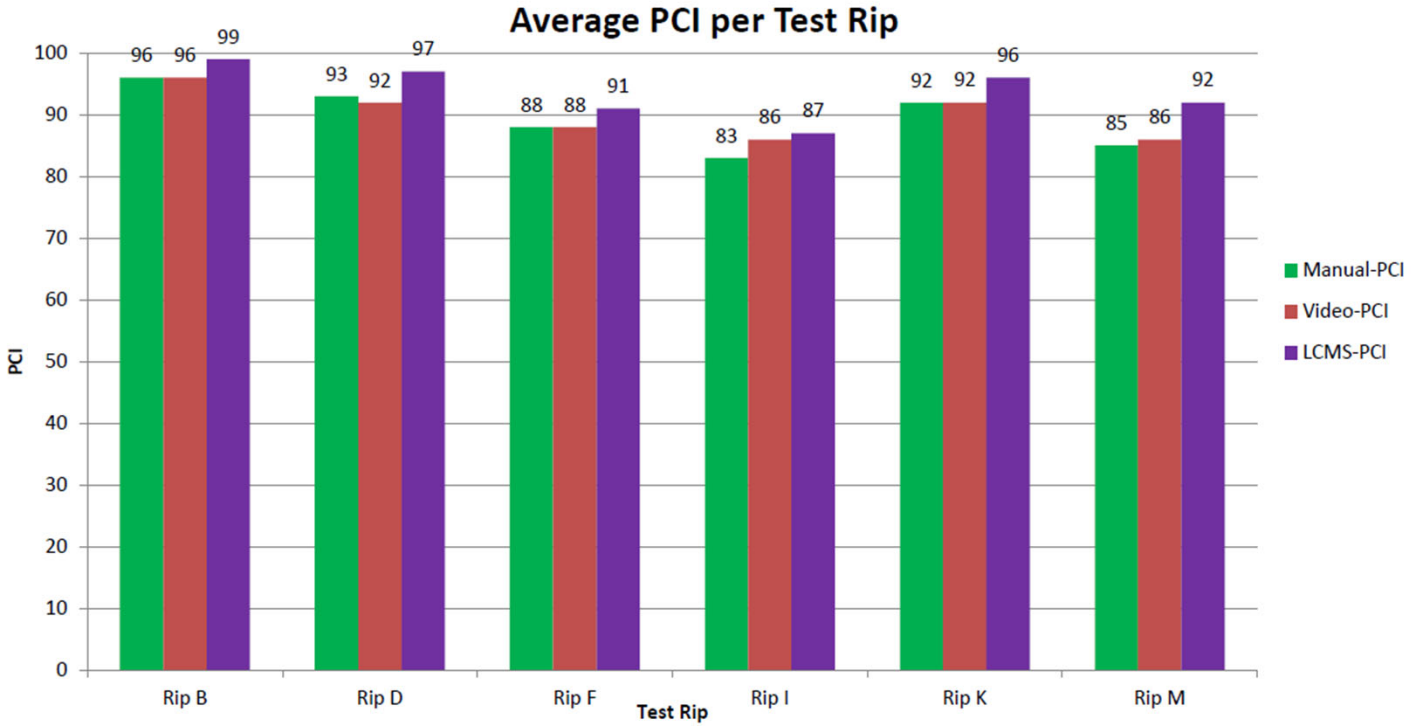


# Case Study of Automated vs. Manual Data Collection

- Performed by Pavement Management Services (PMS) Ltd.
- Runway asphalt pavement evaluated using:
  - Manual data collection
  - Automated data collection via HD cameras and manual data interpretation
  - Automated data collection via 3D laser imaging and manual data interpretation

# Average PCI Comparison

- Manual data collection – 89
- HD cameras – 90
- 3D laser imaging – 94



# Automated vs. Manual Commentary

- Reasonable comparison for asphalt pavements in good condition
- Less comparable as condition worsens and more distresses are present (not part of study)
- Concrete pavements have more challenges to overcome for automated data collection
  - Evaluation of whole slabs
  - Many distress classifications are dependent on ability to produce Foreign Object Debris (FOD)

# Use of Data Collection to Drive Pavement Management Decisions

- Compliance with FAA regulations
- Network-level management
- Strategic-level management
- Project-level assessment
- Maintenance and repair plans
- Troubleshooting and forensics
- Communication to stakeholders

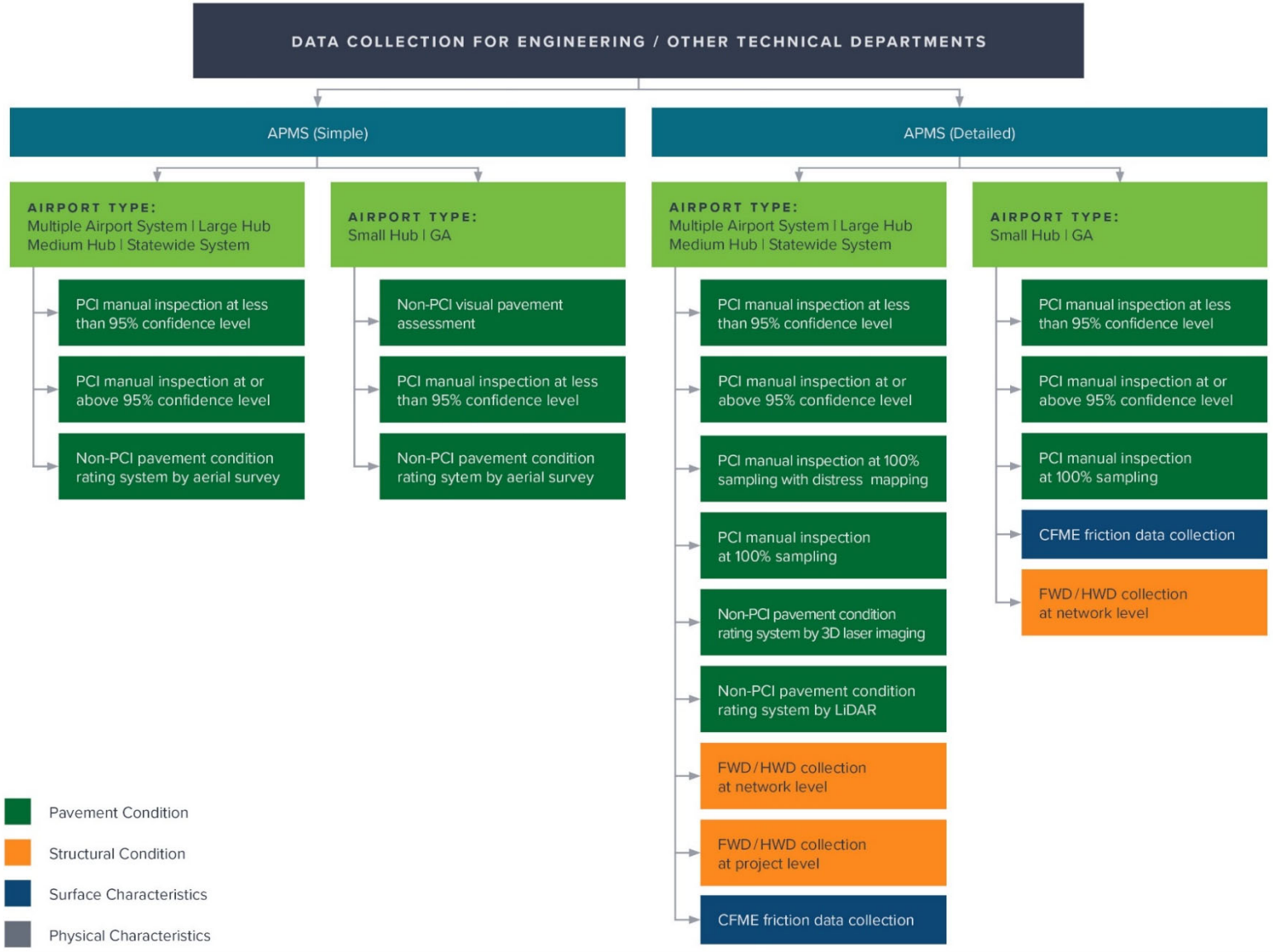
# Matching Condition Data Type and Uses(s)

- Goal is to collect appropriate data that will be used effectively by airports
- Data use controls which collection methods are implemented
- Decision trees presented in ACRP Research Report 203 provide guidance to match condition data types and use(s)

# Decision Trees

- Organized by purpose, airport size, and user
- Decide how the data will be used and follow decision trees to select the possible data collection methods
- Evaluate the most common methods
  - Do the most common data collection methods meet all specific uses?
  - Will a combination of methods be required?
  - Identify other factors
  - Estimate the cost and value

# Sample Decision Tree – Engineering (APMS)



# Future of Airport Pavement Data Collection and Interpretation Goals

- Improved compliance
- Faster data collection and processing
- Lower costs
- Greater accuracy
- Improved access to data
- Improved automated distress detection
- ASTM standard for automated data collection

# Airfield Data Collection Summary

- Several automated data collection technologies are available; need to choose the right one for your specific need
- Currently not able to identify all distresses within ASTM D5340
  - Is that necessary for your intended use?
  - Field verification may be needed
- Technology is evolving; it is inevitable that it will become the standard

# Certification and Verification of Transverse Profile Data

## TPF-5(299)– Rutting, Cracking, and Faulting

**John B. Ferris**
Vehicle Terrain Performance Laboratory (VTPL), Virginia Tech
Speaking as a professional and not as a representative of the university

**Craig T. Altmann**
Virginia Military Institute (formerly of VTPL)

June 10, 2020

# Objectives

| | |
|---|---|
| Capability: | Assess precision and accuracy of highway speed Transverse Pavement Profiler (TPP) measurements |
| Requirements: | Determine requirements for Rut Depth, Cross-slope, Edge/Curb Detection |
| Assessment: | Evaluate if TPP measurement capabilities satisfy requirements |

# Agenda

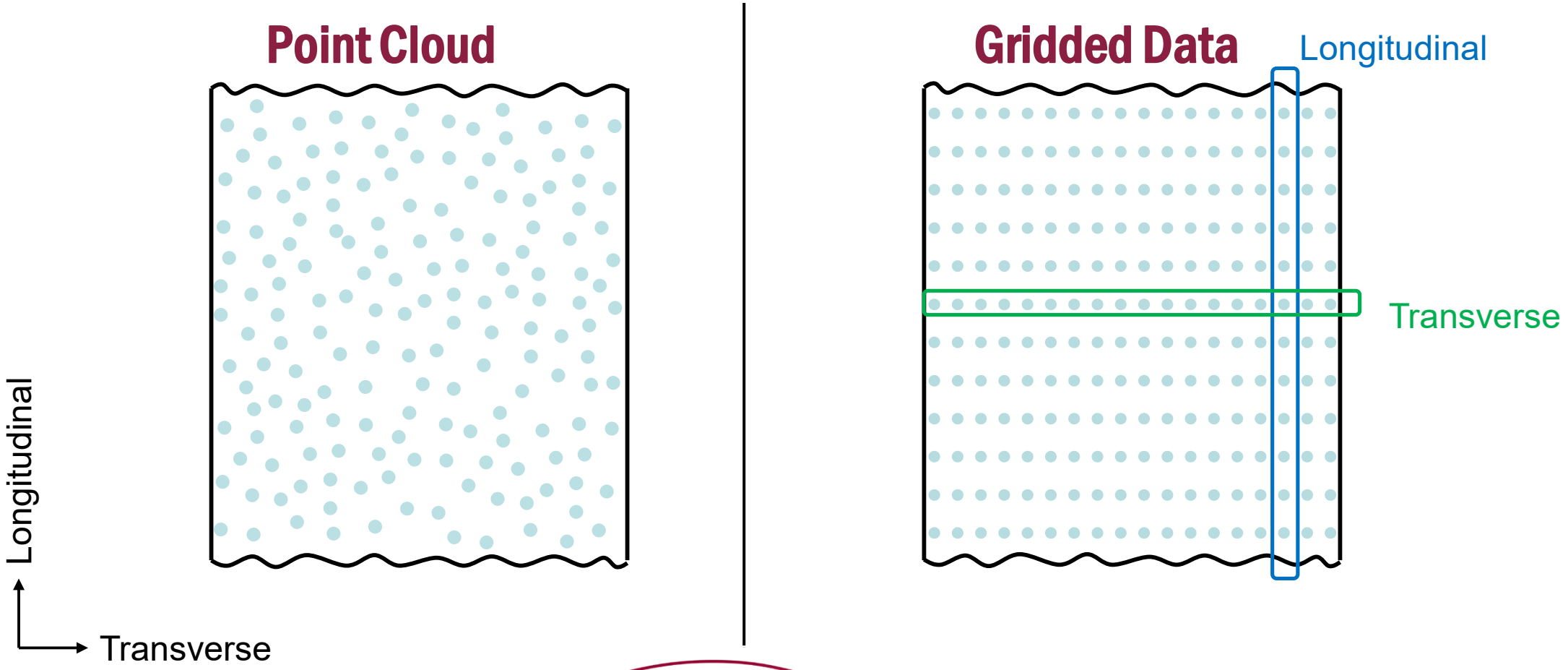
Definitions and General Approach

Transverse Pavement Profiler (TPP) Standards (4)

Ground Reference Equipment (GRE) Measurements

Assessment

# Definitions: Point Cloud vs. Gridded Data



# Definition: Mapping Sensor vs. Localization Sensor

## Mapping Sensor

*acquires road surface measurements*

**Examples:**

- Laser/Lidar
- Camera
- Radar

## Localization Sensor

*acquires pose of the TPP system*

**Examples:**

- GPS
- IMU
- Wheel encoder
- Accelerometers

# General Approach

Chain of Traceability to Certification Objects (Ground Reference/"Truth")

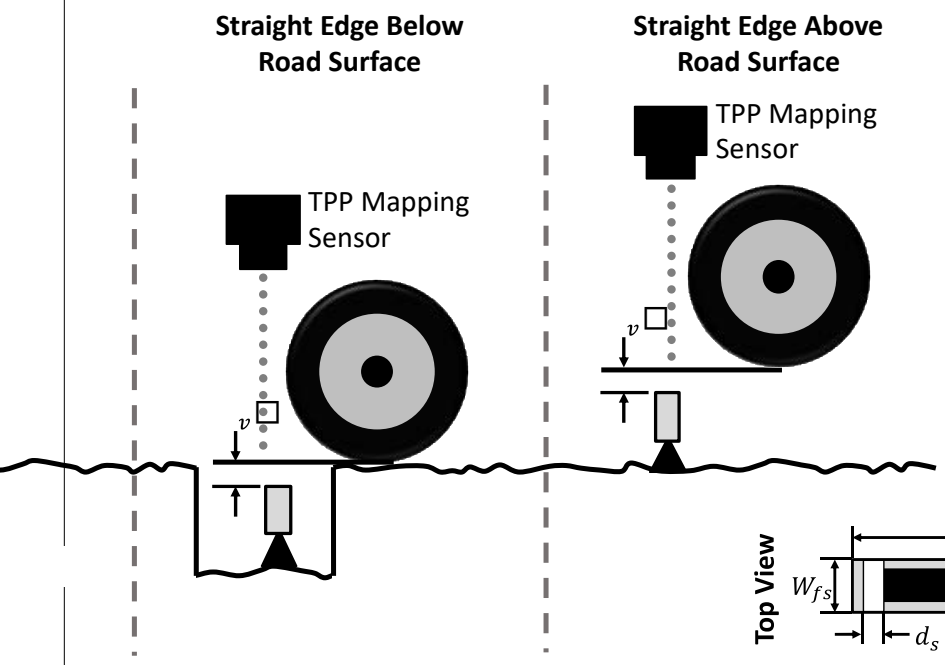
- Begin all assessment with Certification Objects whose dimensions are measured by a certified laboratory (NIST, ISO…)
- All Certification Objects are known to within some accuracy and precision that is traceable to the Cert. Lab
- Subsequent assessments of components/systems/processes are limited by the accuracy and precision of the previous step

Cert. Lab → Cert. Object → Sensor/Processing → System/Processing

# TPP Performance Tests

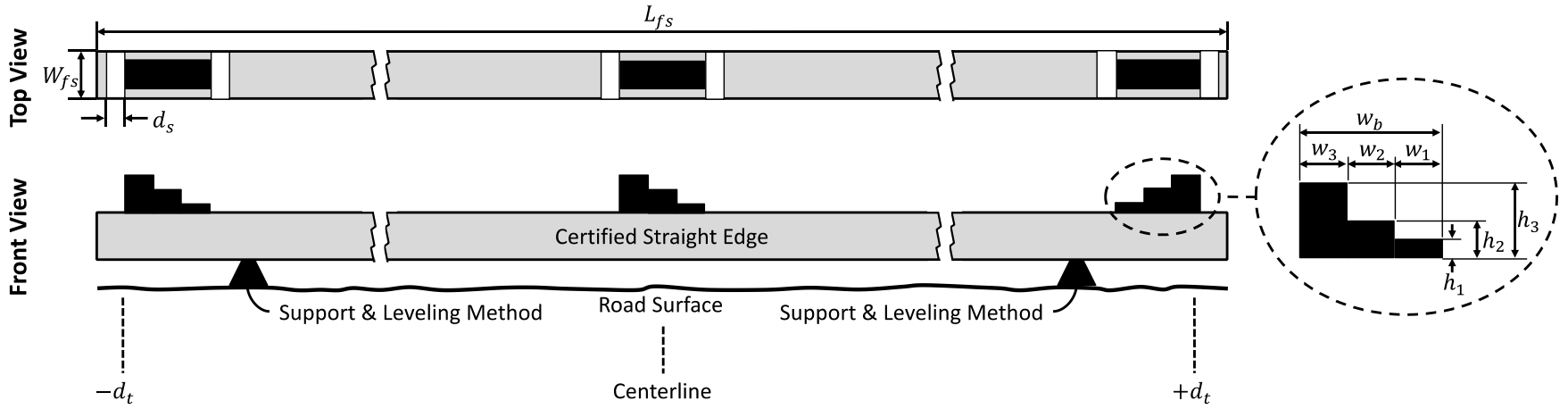
| | |
|---|---|
| **Static performance** | Evaluate static road surface measurement ability<br>Assess mapping sensors |
| **Body motion cancelation** | Evaluate ability to remove body movement<br>Assess localization sensors, fuse mapping and localization |
| **Navigation drift mitigation** | Evaluate drift in global position<br>Assess localization sensors, fuse localization sensors |
| **Typical highway** | Evaluate complete TPP during typical highway operations<br>- Transverse Capability<br>- Ground Reference* |

# Static Performance

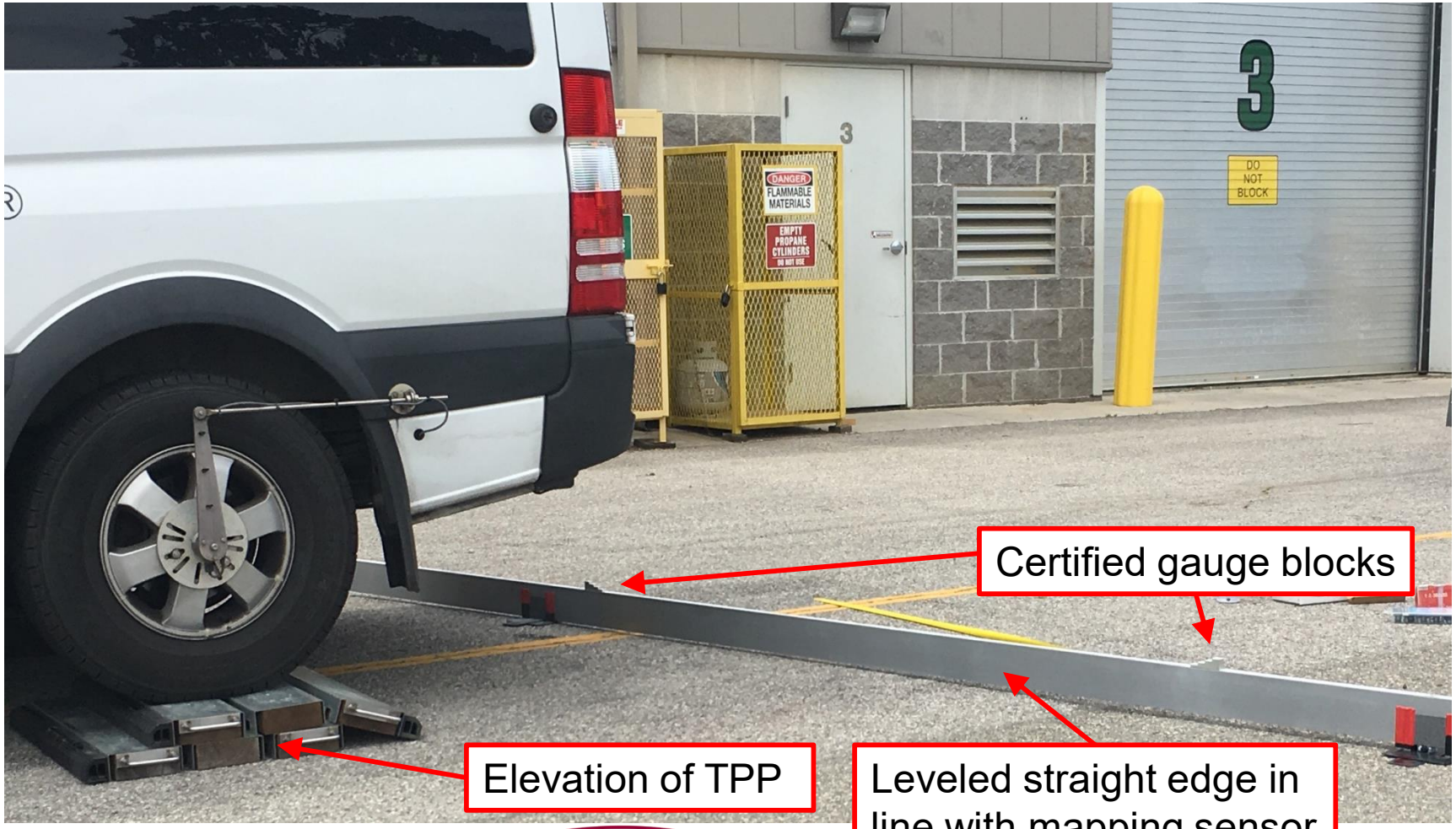



Assess:
mapping sensors

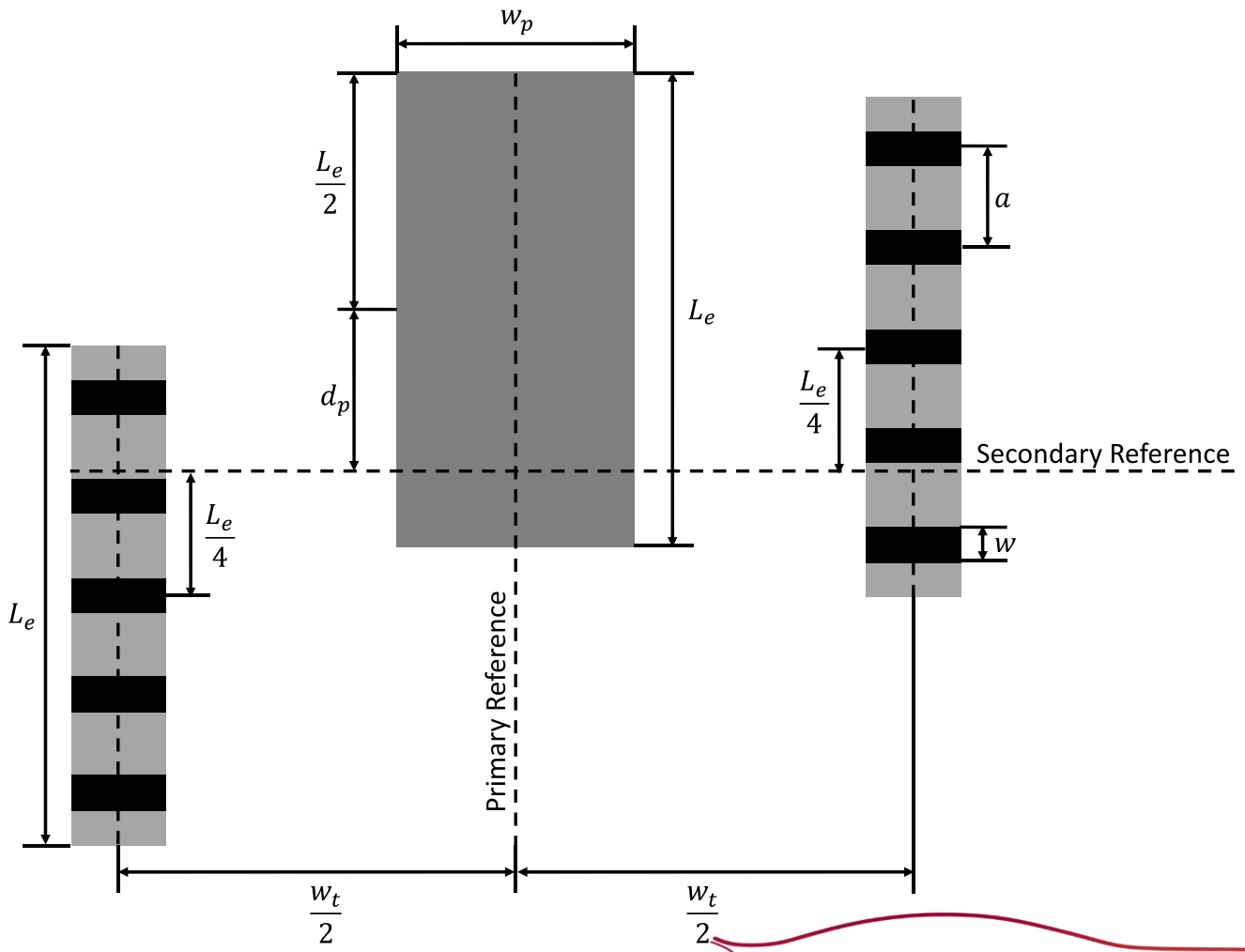
| Output Test Statistics |
|---|
| Transverse Measurement Resolution |
| Transverse Measurement Error |
| Vertical Measurement Resolution |
| Vertical Measurement Error |
| Total Transverse Width |
| Straightness Error |



# Static Performance



# Body Motion Cancelation



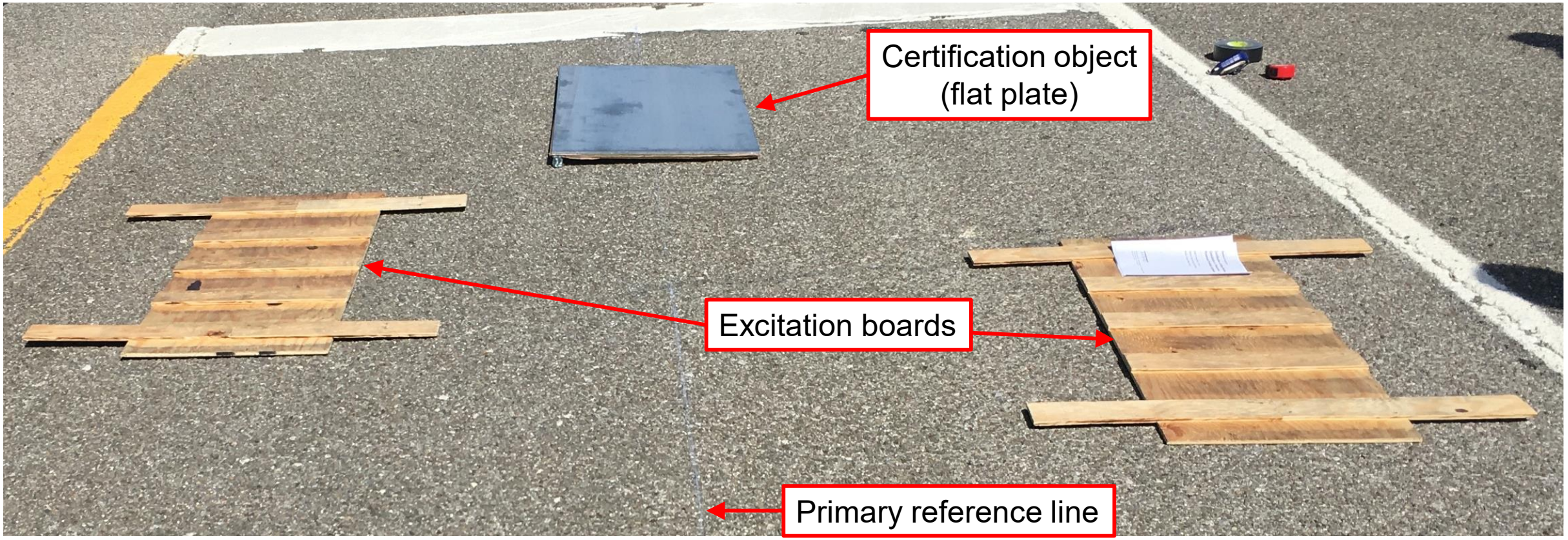

**Output Test Statistics**

**Vehicle Body Motion Error**

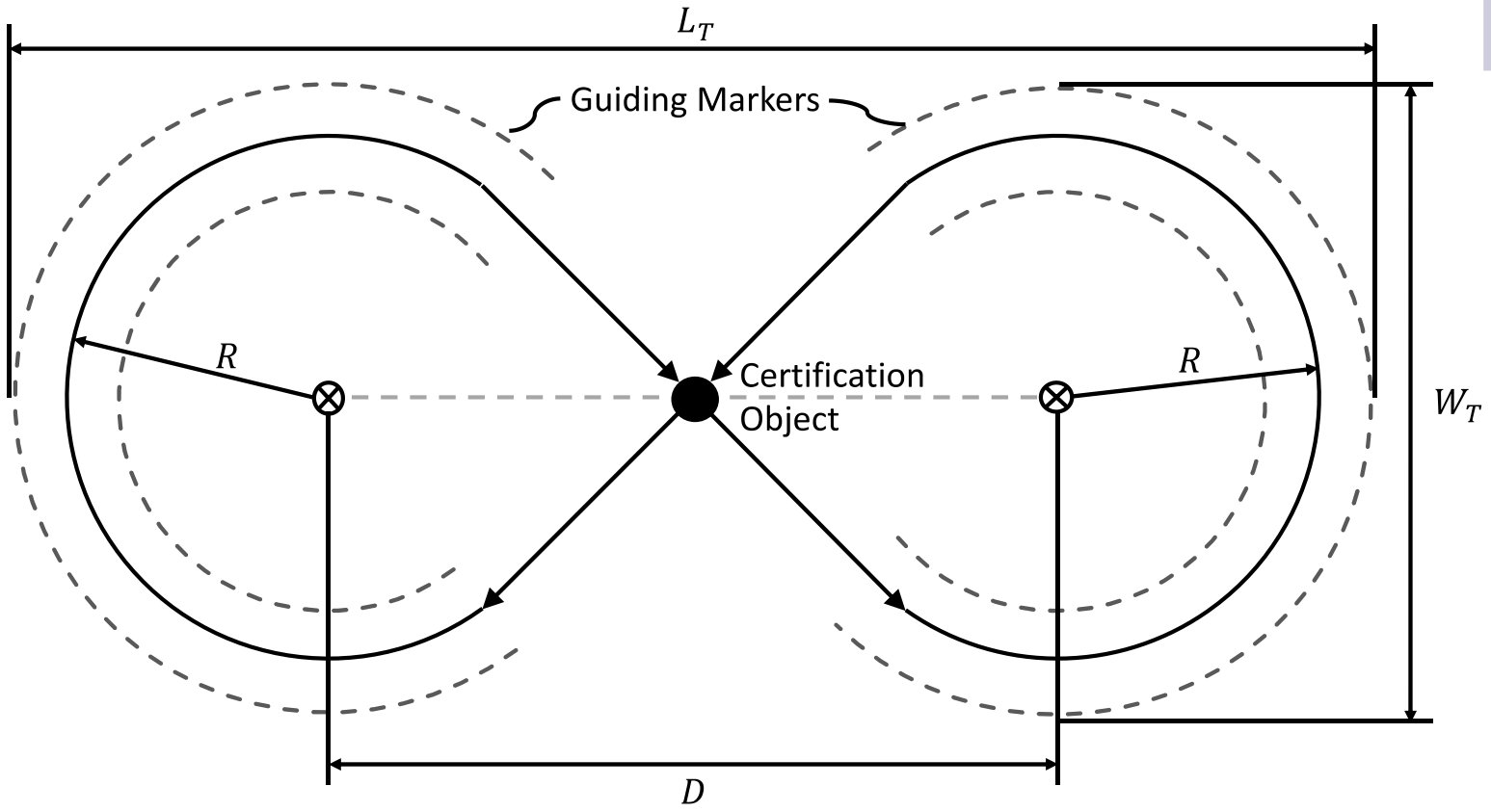
Assess:

- Localization sensors (IMU/gyro, accels)
- Ability to fuse mapping and localization sensors

# Body Motion Cancelation



# Navigation Drift Mitigation

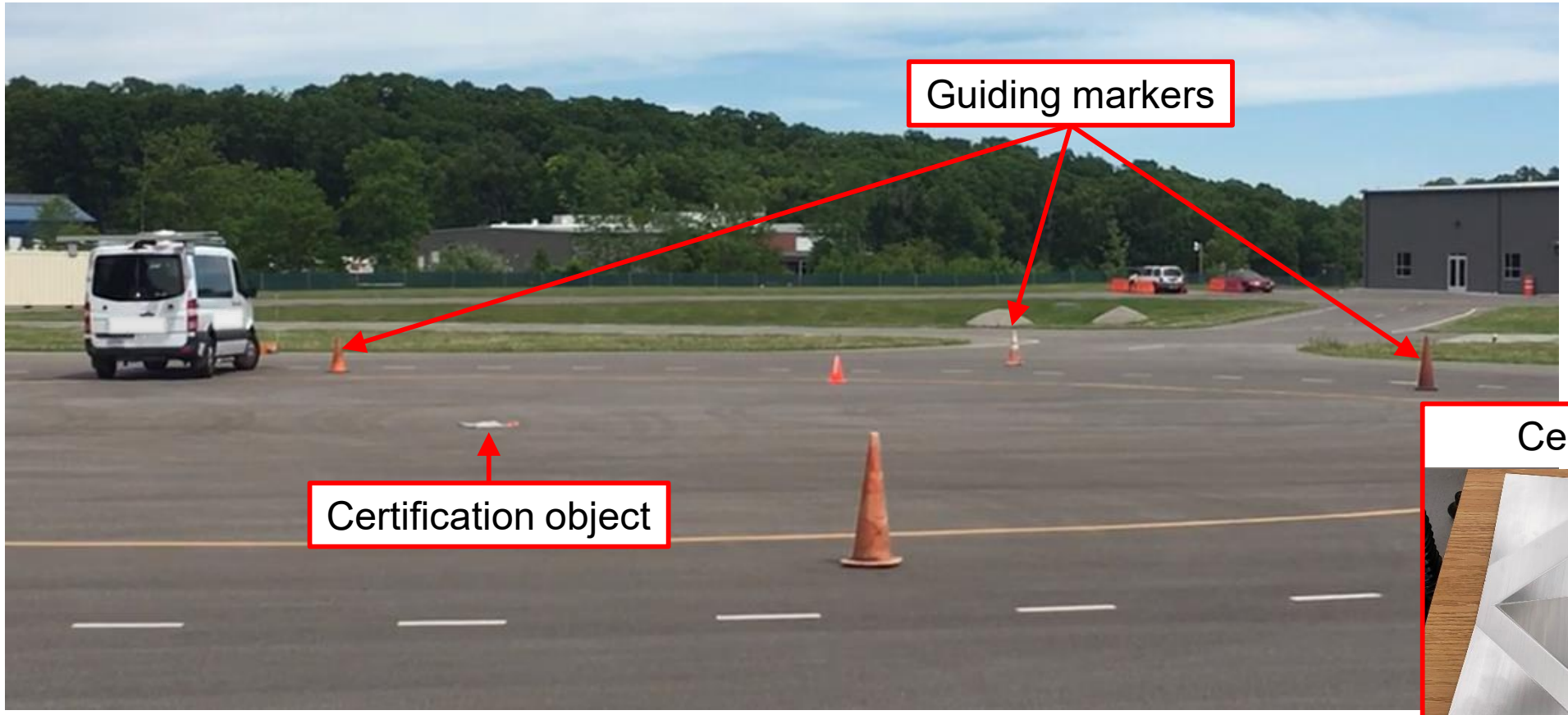



| Output Test Statistics |
| --- |
| Easting Position Error |
| Northing Position Error |
| Elevation Position Error |

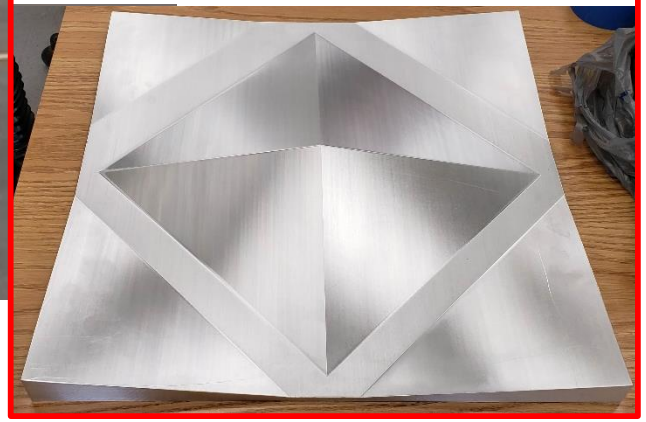
Assess:

- Localization sensors (GPS, IMU/gyro, accels)
- Ability to fuse various localization sensors

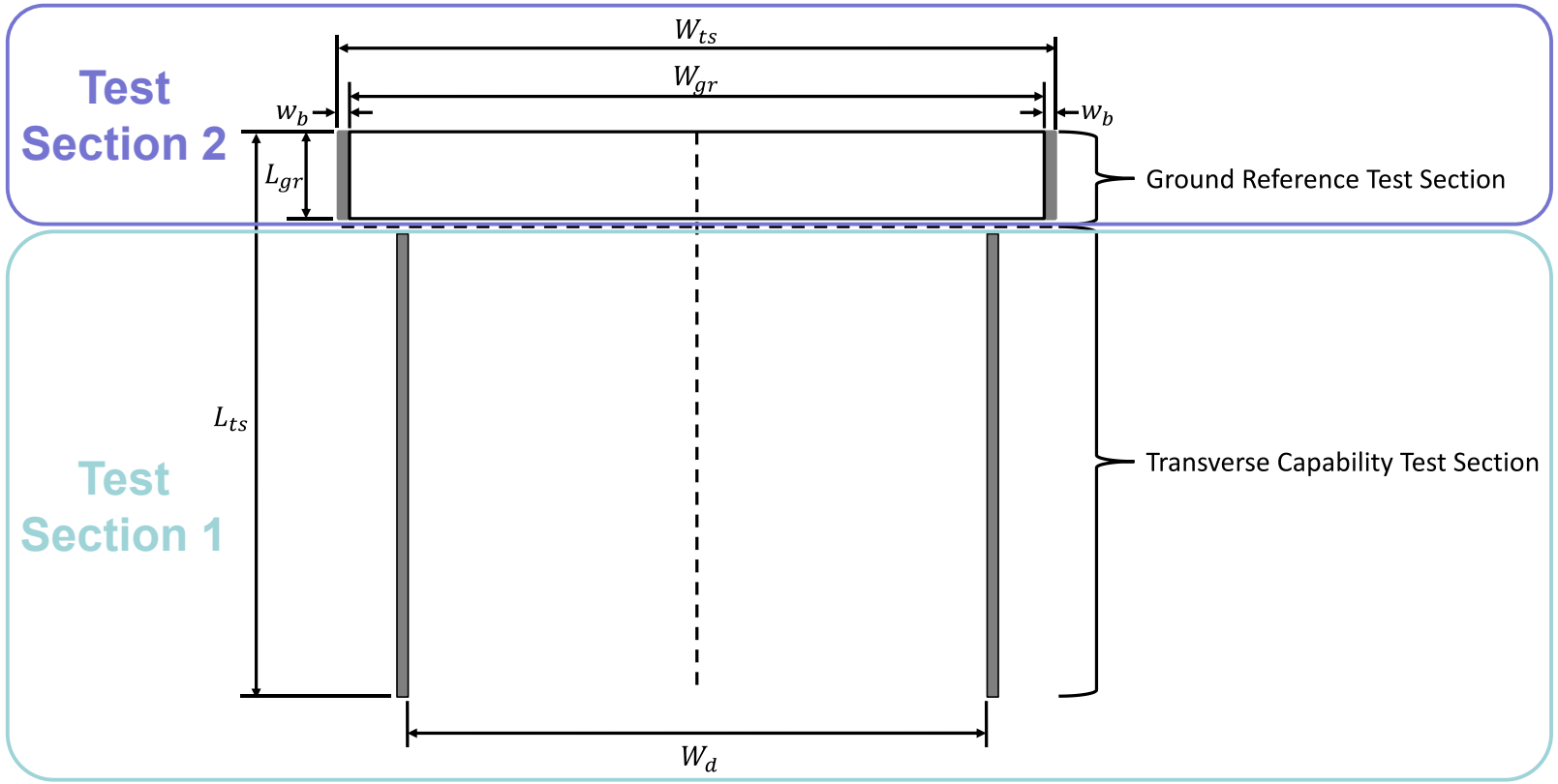
# Navigation Drift Mitigation




Certification object

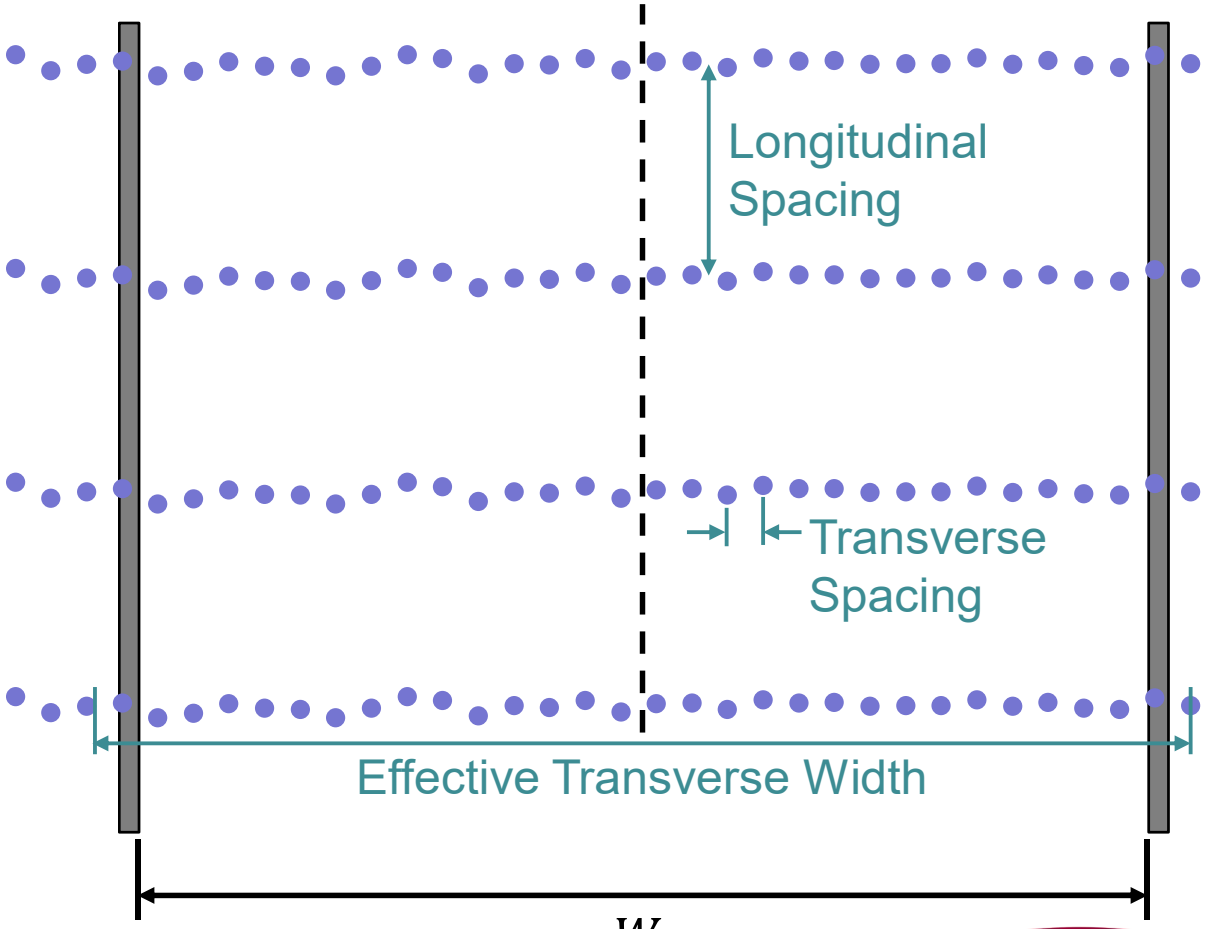


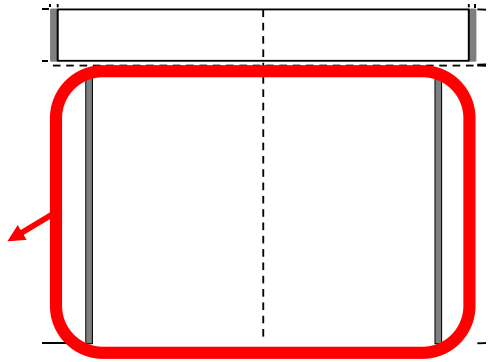
# Typical highway performance




| Output Test Statistics |
|---|
| Transverse Measurement Spacing [1] |
| Effective Transverse Width [1] |
| Vertical Measurement Spacing [1] |
| Longitudinal Measurement Spacing [1] |
| Point Cloud Vertical Error [2] |
| Gridded Data Vertical Error [2] |
| Cross Slope Error [2] |
| Rut Depth Error [2] |
| Edge/Curb Transverse Location Error [2] |
| Edge/Curb Vertical Magnitude Error [2] |

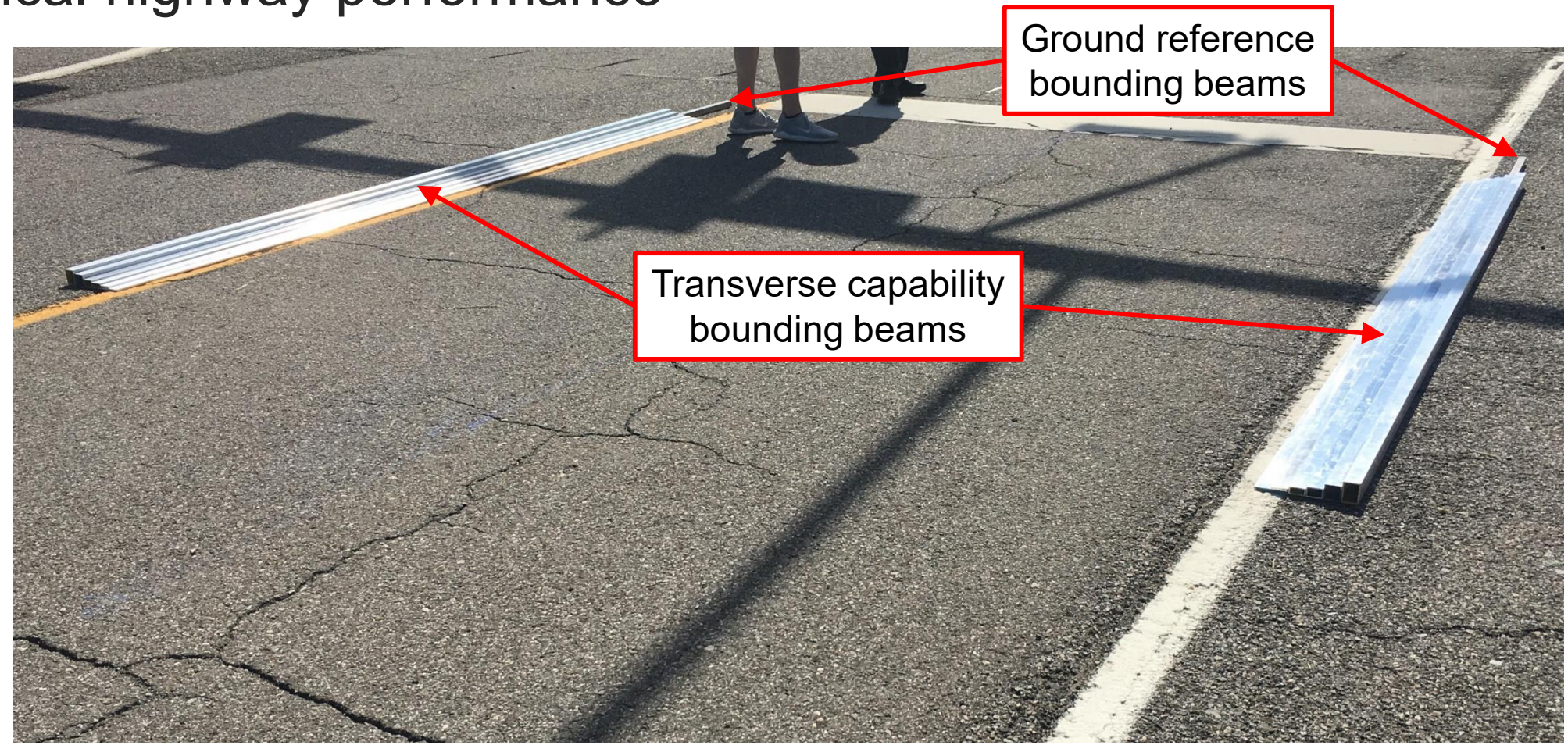
# Transverse Capability Test – Section 1



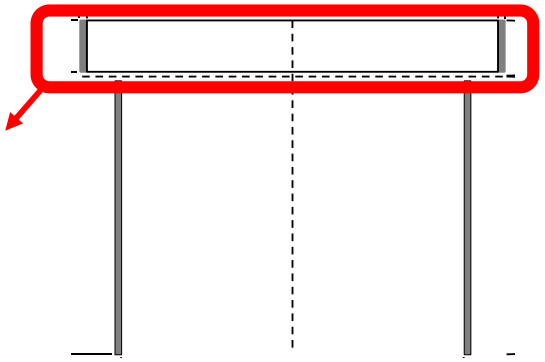
Transverse Capability Test Section

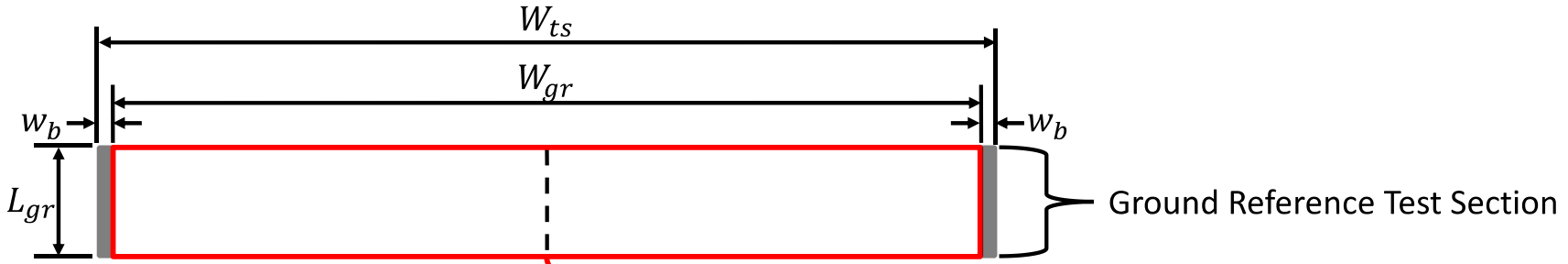
# Typical highway performance

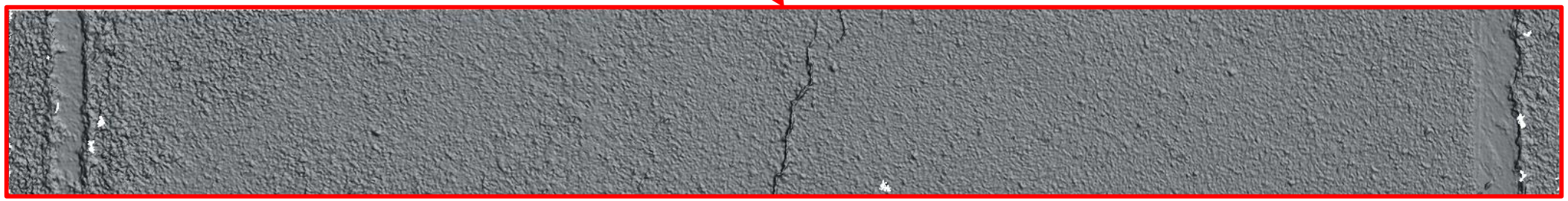


# Ground Reference Test – Section 2

*A segment of road with **reference** measurements is needed to determine the accuracy of the data requirements.*

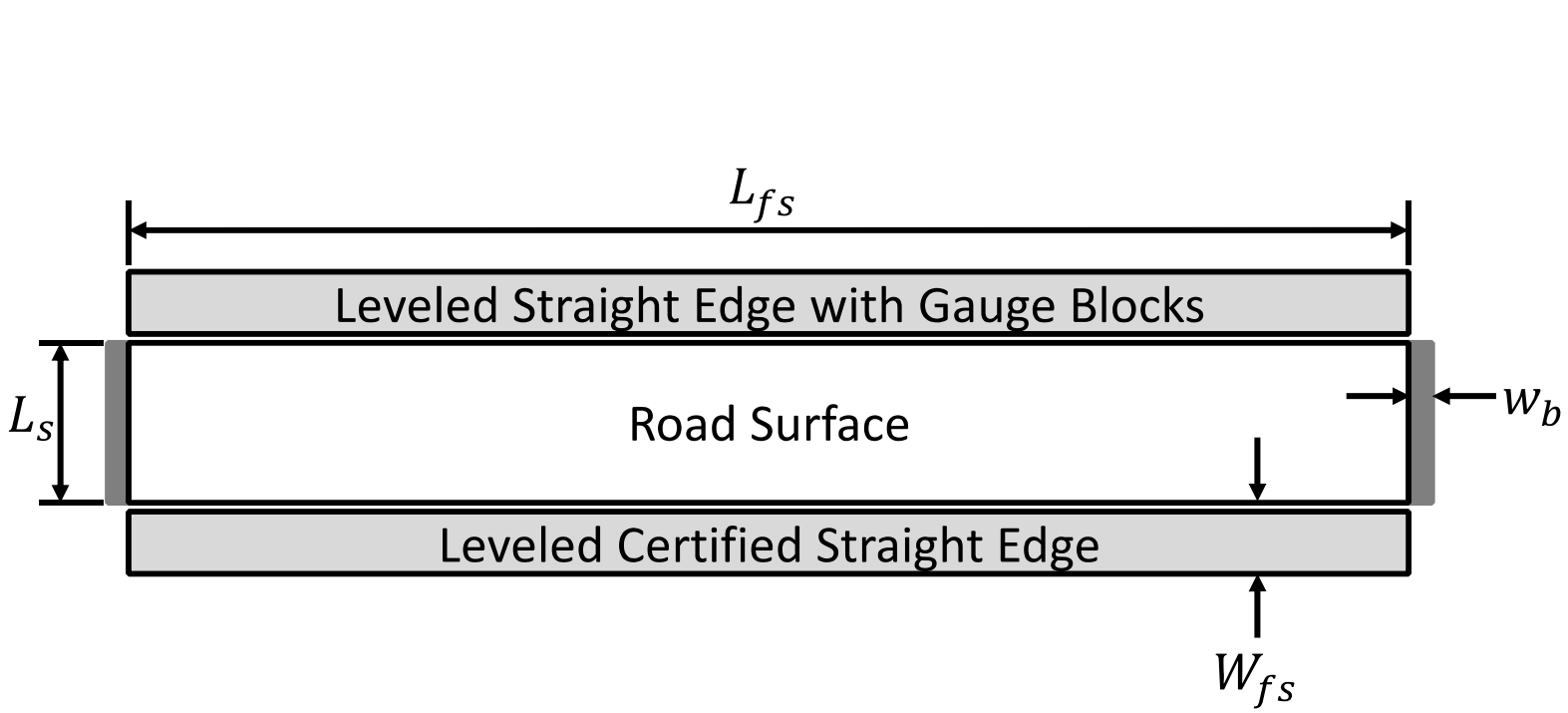


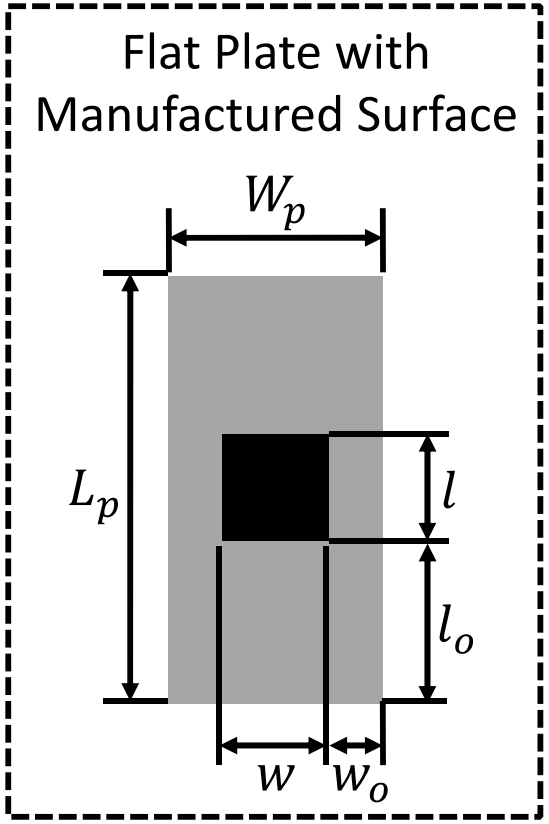


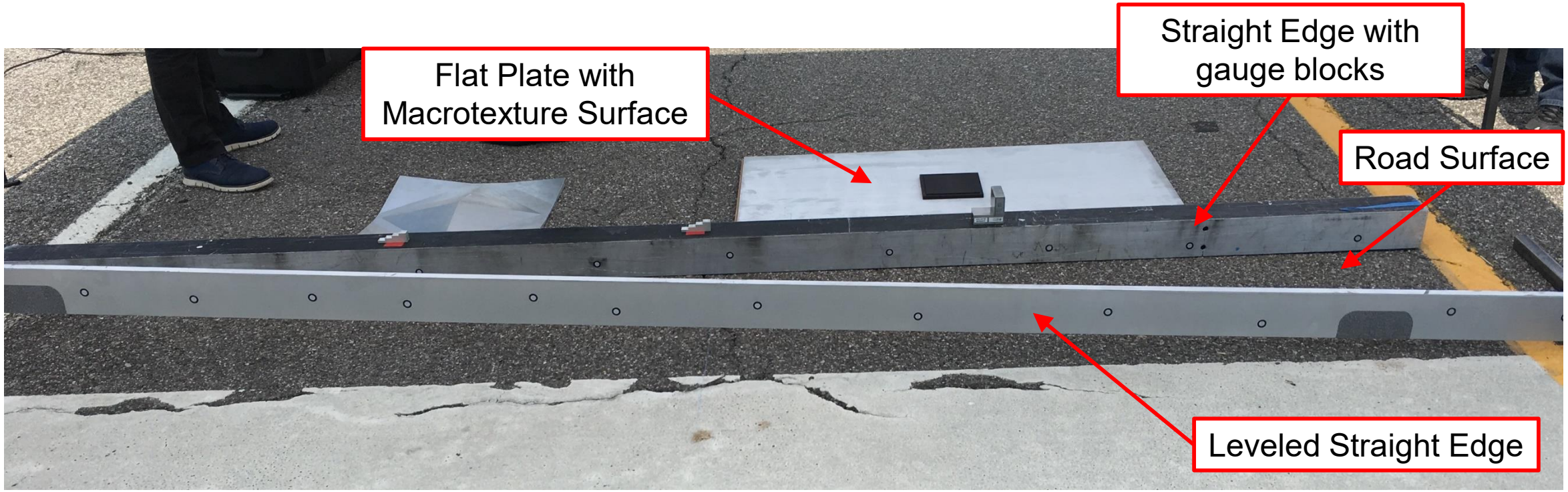
# Acceptance of GRE Measurements

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



# Acceptance of GRE Measurements

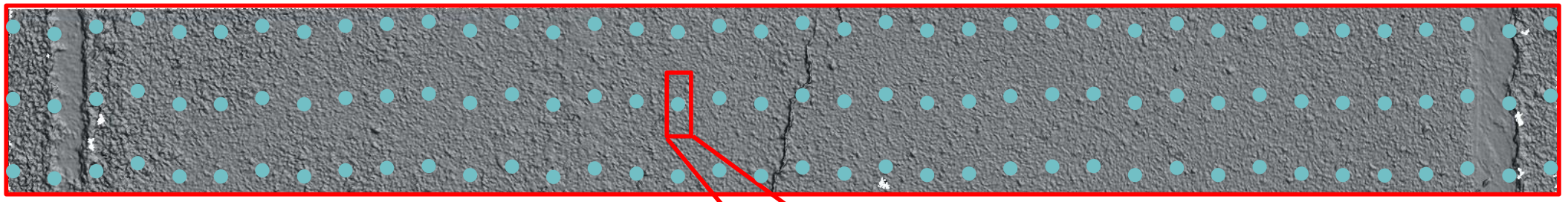


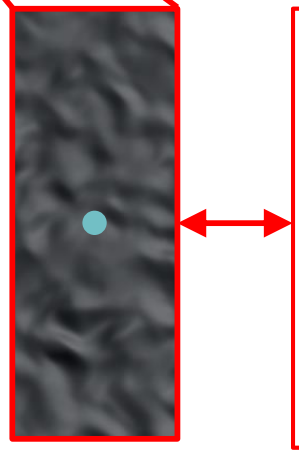
# Acceptance of GRE Measurements

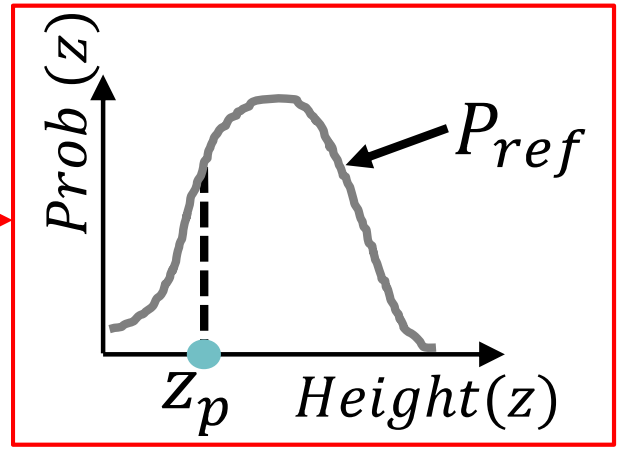
Recall Chain of Traceability:

Cert. Lab →
Cert. Object →
Sensor/Processing →
System/Processing

# Ground Reference Test Section: TPP Measurements

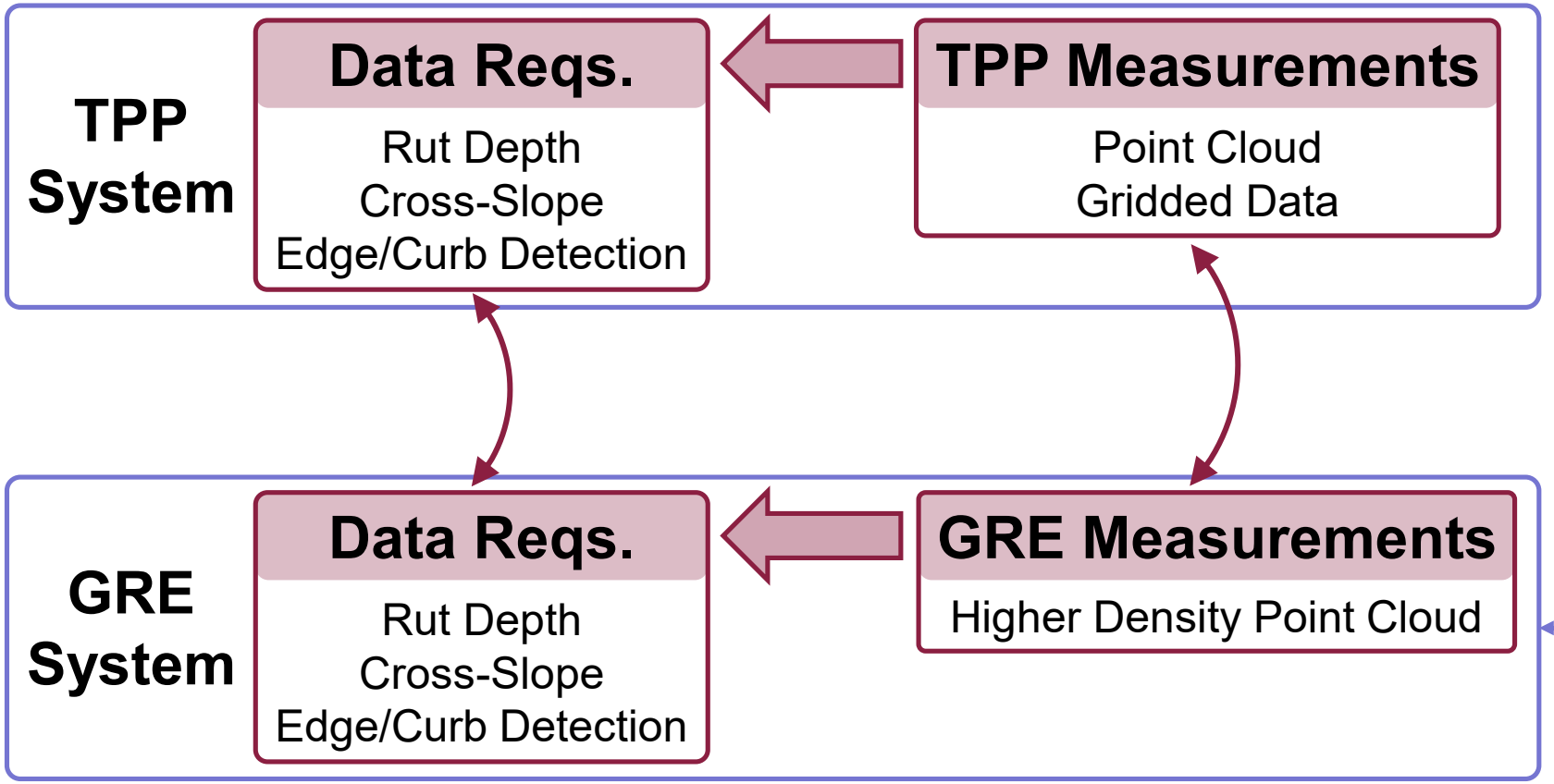







*Account for uncertainty in measurements*

# Assessment of Data Requirements




Recall Chain of Traceability:
- Cert. Lab →
- Cert. Object →
- Sensor/Processing →
- System/Processing

Higher accuracy and precision

# 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 | | | | | |
| Transverse Width | | | | | |
| ⋮ | | | | | |

# Summary

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

Questions, either:

1. Type your question in the chat window
2. Click the ‘Raise Hand’ button

Thank you

# Summary

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Thank you

# Today's Presenters

Nima Kargah-Ostadi, iEngineering

John Ferris

Doug Frith

QES Quality Engineering Solutions
Engineering • Inspection

Andy Mergenmeier

U.S. Department of Transportation
Federal Highway Administration

Monty Wade

applied pavement TECHNOLOGY

**#TRBwebinar**

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