Achieving High Correlations of Inertial Profilers with Reference Profilers at the Smart Road

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Pavement Evaluation 2014

Objectives

- State DOTs want to certify Inertial Profilers using ASTM E950 which requires 94% IRI Cross Correlation of candidate Inertial Profiler with Reference Profiler
- Reference profiler must provide 98% Accuracy and Repeatability Cross Correlation profiles
- A Certification Site must be established that supports High Cross Correlations—Smart Road?
- Train Operators—Reference Profiler Rodeo!
- Finally, need to Devise Strategies to Achieve High Cross Correlations with Inertial Profilers

May 2014
Reference Profiler Rodeo

1. Provide Operator Training to Reference Profiler Operators
2. Provide Certification Site Training to Reference Profiler Operators
3. Compare Profiles Collected by Reference Profilers from different State DOTs with different operators

Classroom Operator Training

- General Description of SurPRO Instrument
  - General Arrangement, sensors and electronics
  - Basic Theory and Method of Data Acquisition
  - Specifications
- Road Profiling
  - Road Theory and IRI
  - Operation using Keypad and Display
  - How to Collect Data
- Data Analysis
- Maintenance

Profiler Firmware, Software and Hardware Configuration

- Installed latest firmware upgrades to 4000 model software without requiring hardware replacement. Supports constant distance sampling.
- Installed latest software upgrades to 4000 model
- Inspected and adjusted hardware to confirm correct configuration and performance
  - Performed acceleration compensation test

Operator Hands on Training in the Field

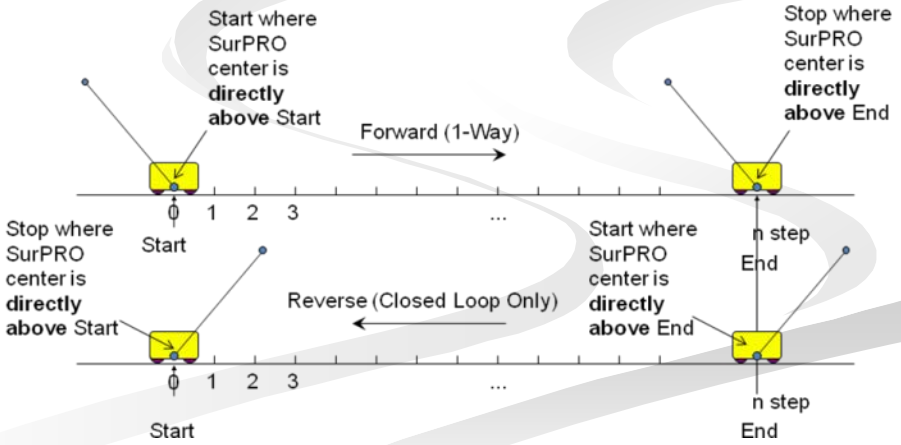
- Powering on and configuring reference profiler by setting parameters using menu
- Starting (accelerating) and stopping (decelerating) the profiler
- Keeping steady speed
- Keeping vertical orientation
- Using pointer to precisely follow profile line.
- Running closed loop profiles

Profiler Calibration and Testing

- Prepare Calibration Site
  - Measured precise 200 foot long profile using accurate 300 foot steel tape
  - Marked high visibility chalk line
- Perform Distance (DMI) Calibration
  - Set 200 foot distance calibration parameter in menu
  - Run full length in distance calibration mode

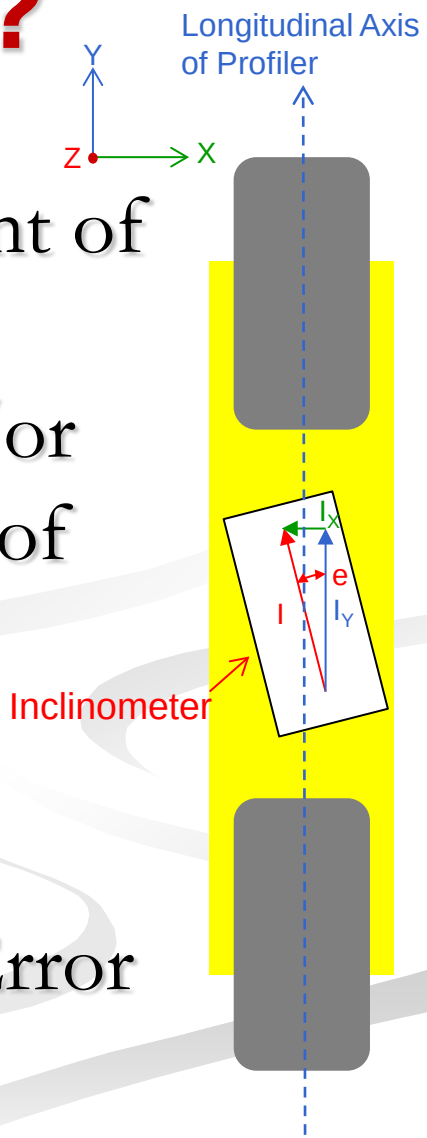
Profiler Calibration and Testing

- Cross Axis Calibration
  - 3 forward runs with intentional tilting at 3 different tilts: left 5°, right 5° and 0° (vertical or no tilt)
  - Use Cross Axis Autocalibration to calculate ideal cross axis calibration
- Closed Loop Profiles
  - Confirm performance



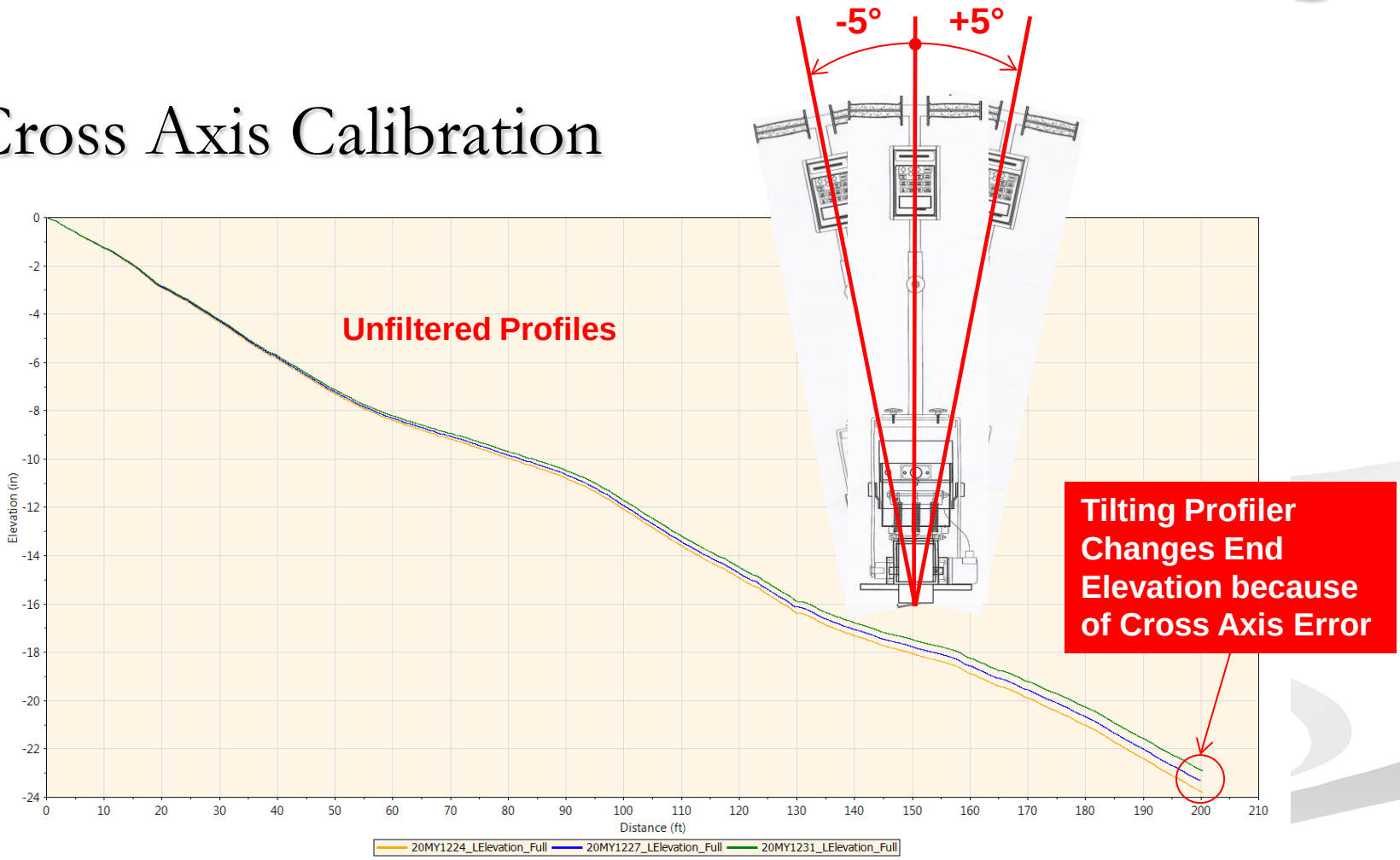
What is Cross Axis Error?

- Small misalignment of sensing element of inclinometer accelerometer with longitudinal axis of its own case and/or of the case with the longitudinal axis of profiler. A rotation around z axis.
- Rotation of inclinometer by angle e results in sensitivity in cross axis (x direction) of Ix. This is Cross Axis Error which is a profile signal error.



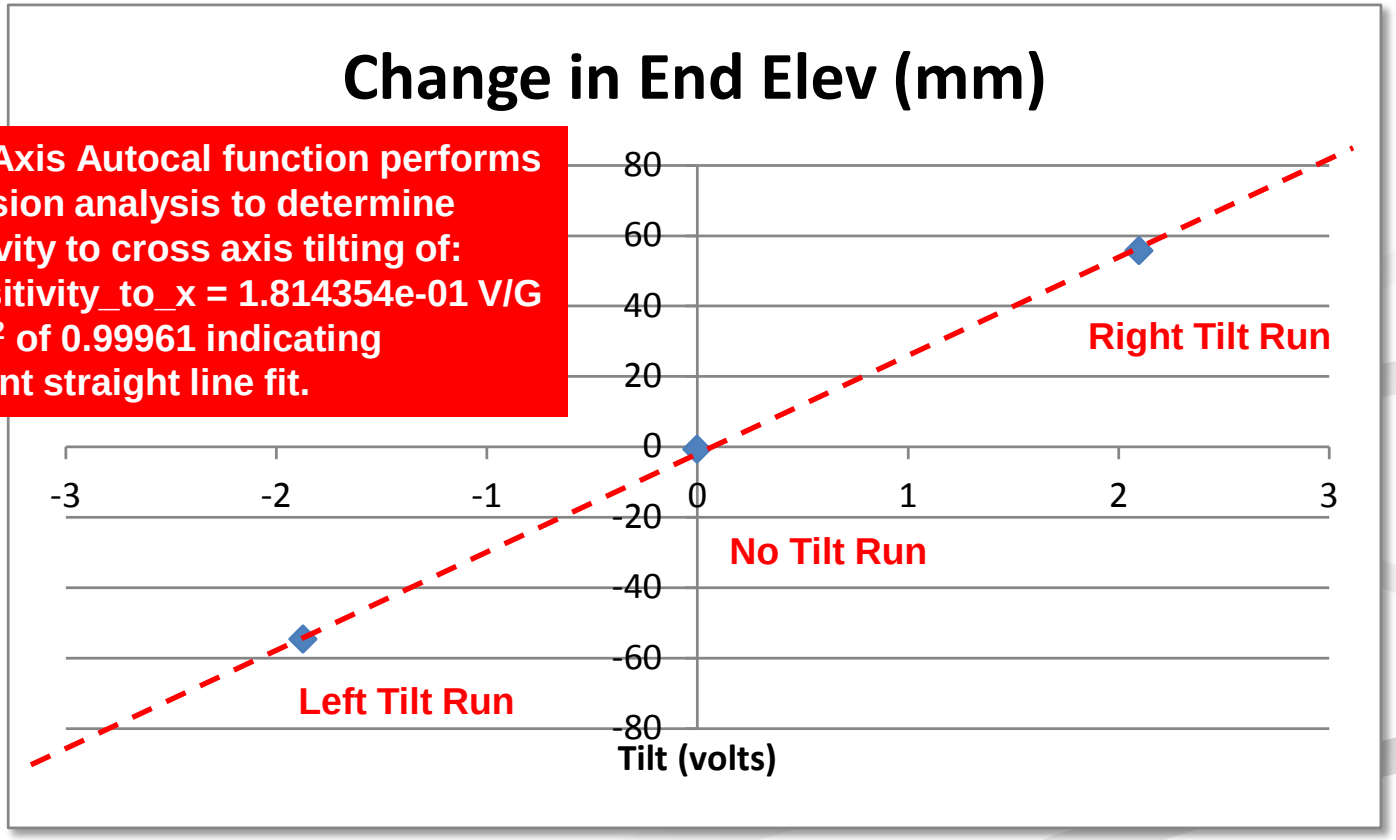
Profiler Calibration and Testing

- Cross Axis Calibration



Profiler Calibration and Testing

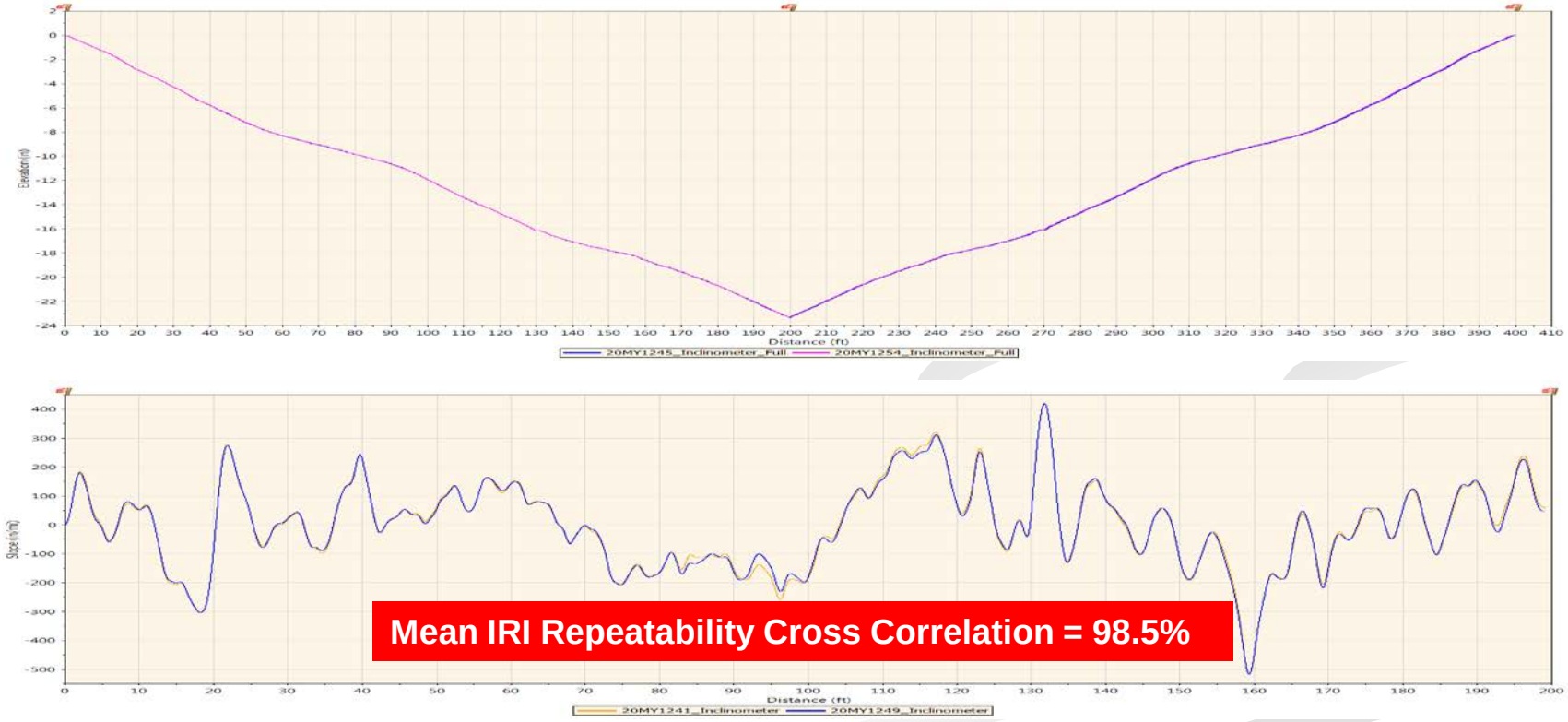
- Cross Axis Calibration



Cross Axis Autocal function performs regression analysis to determine sensitivity to cross axis tilting of: fi_sensitivity_to_x = 1.814354e-01 V/G With R^2 of 0.99961 indicating excellent straight line fit.

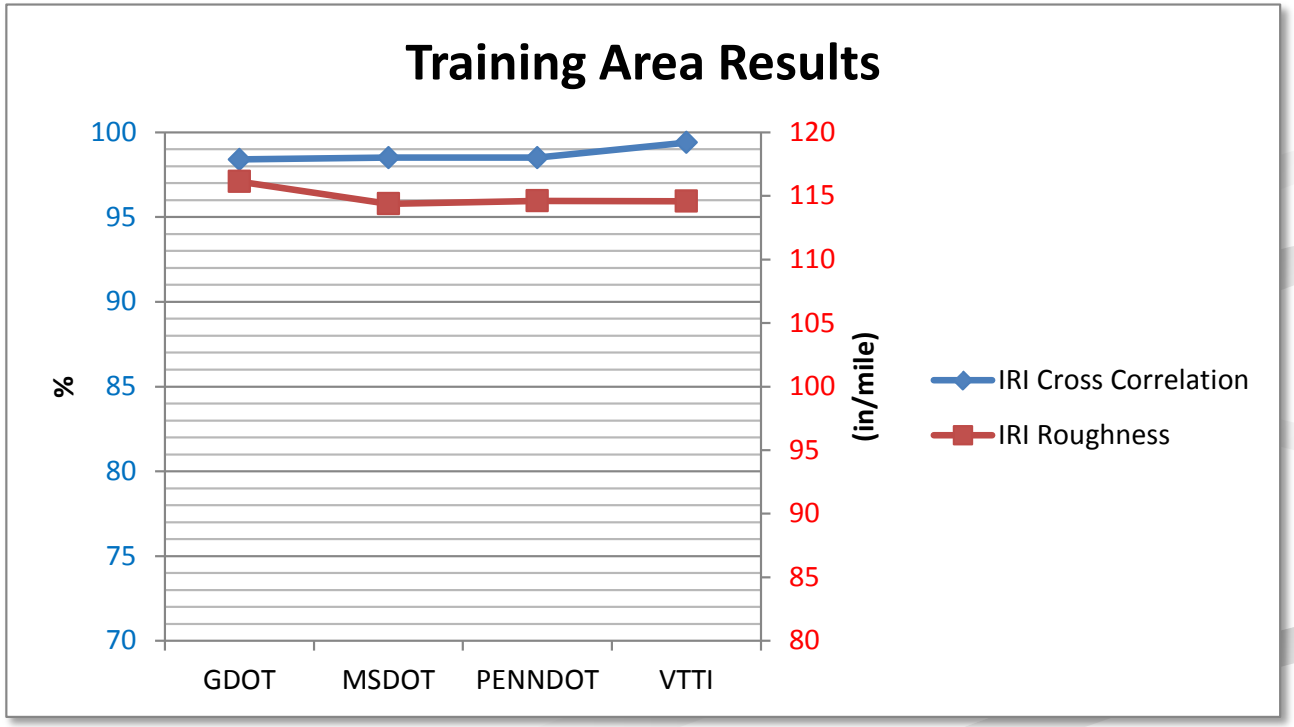
Profiler Calibration and Testing

- Closed Loop Runs



Training Area Results

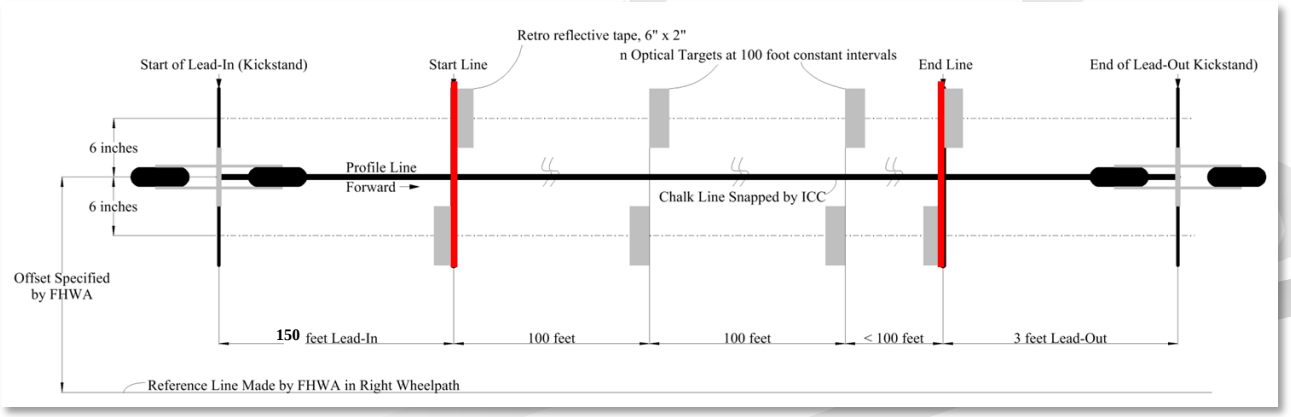
- All participants >98.4% IRI Cross Correlation
- Generally good IRI Roughness agreement



Setting Up Certification Site

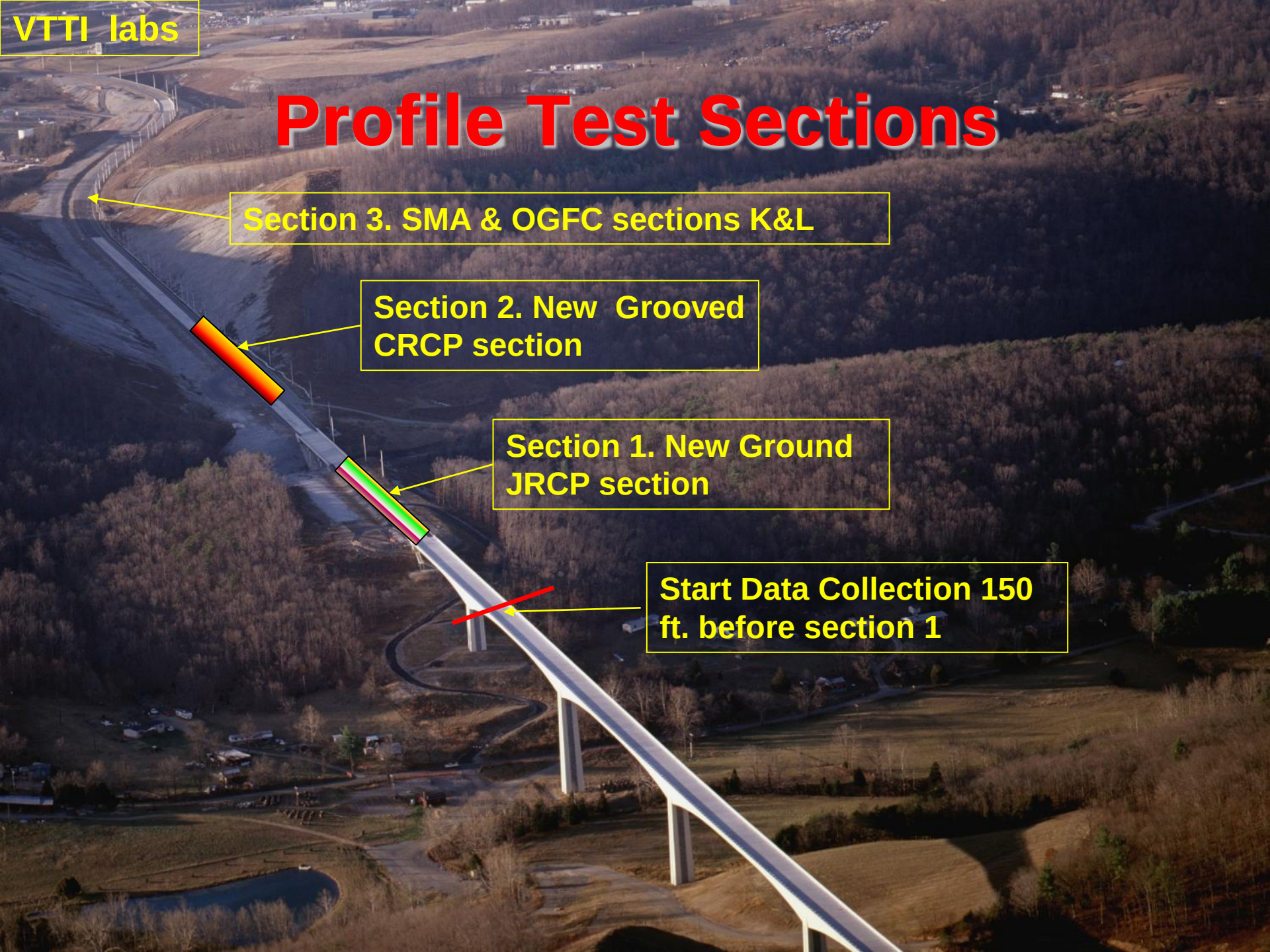
- Measure total 681 feet profile with metal tape including:
  - 150 foot lead-in
  - 528 foot test section
  - 3 foot lead-out
- Snap full length chalk line and transverse start and end line

Typical LWP & RWP

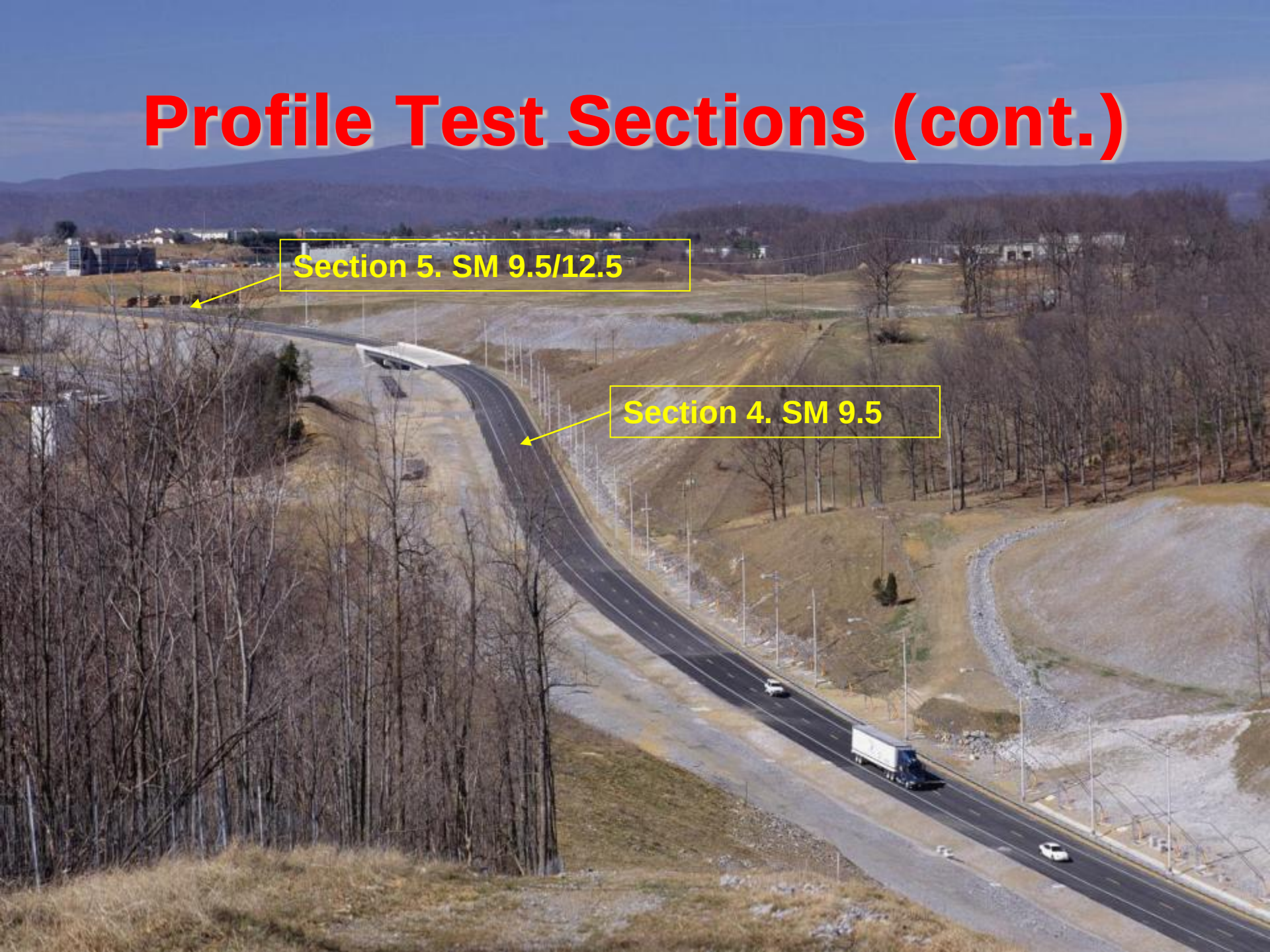


Setting Up Certification Site

Virginia Smart Road


VTTI labs
Profile Test Sections
Section 3. SMA & OGFC sections K&L
Section 2. New Grooved CRCP section
Section 1. New Ground JRCP section
Start Data Collection 150 ft. before section 1

Profile Test Sections (cont.)



IRI Comparison – Section 1 JRCP


Section 1 Ground JRCP

IRI Comparison – Section 2 CRCP

Section 2 CRCP Ground & Grooved

Collecting Profile Data

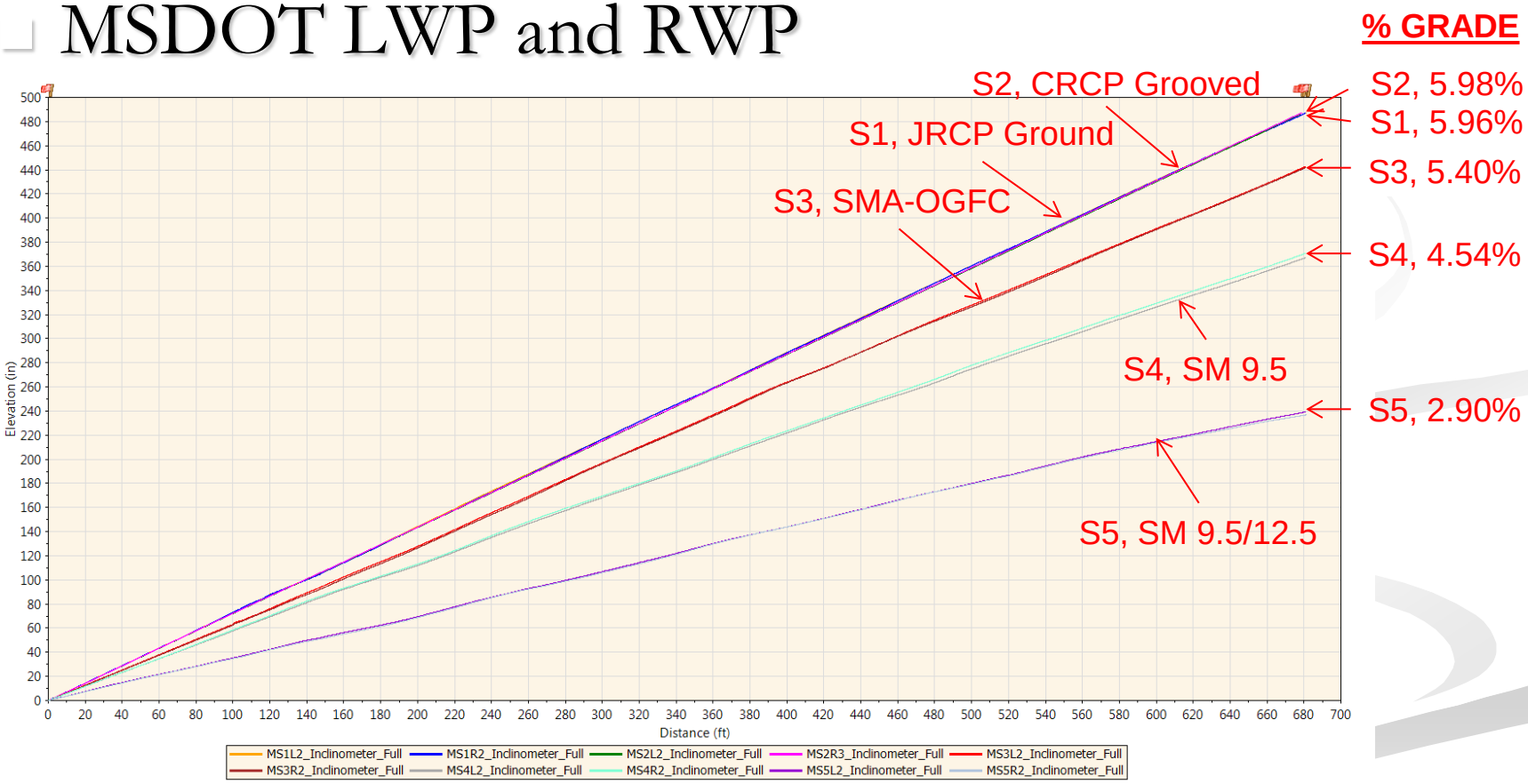
- Both LWP and RWP at each Test Section for S1-S5
- Each Wheel Path
  - One DMI Calibration (save Dist Cal value)
  - One Closed Loop Run (both Forward and Reverse Run and save Elev Cal Value)
  - Two Additional Forward Runs for Total of 3

Collecting Profile Data


SurPRO

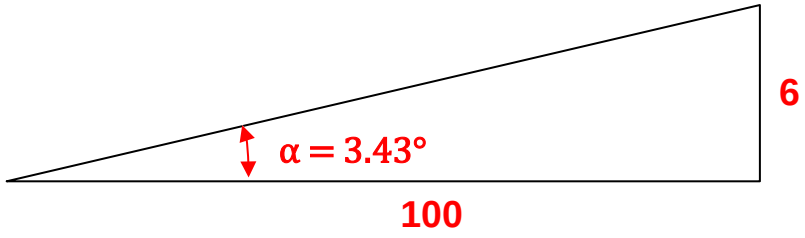
S1-5 Unfiltered Profile Data

- MSDOT LWP and RWP



Effect of Grade on Profiling

- Grade=6%



$$\propto = \tan^{-1}\frac{6}{100}$$

$F_s = 42 \sin \propto$

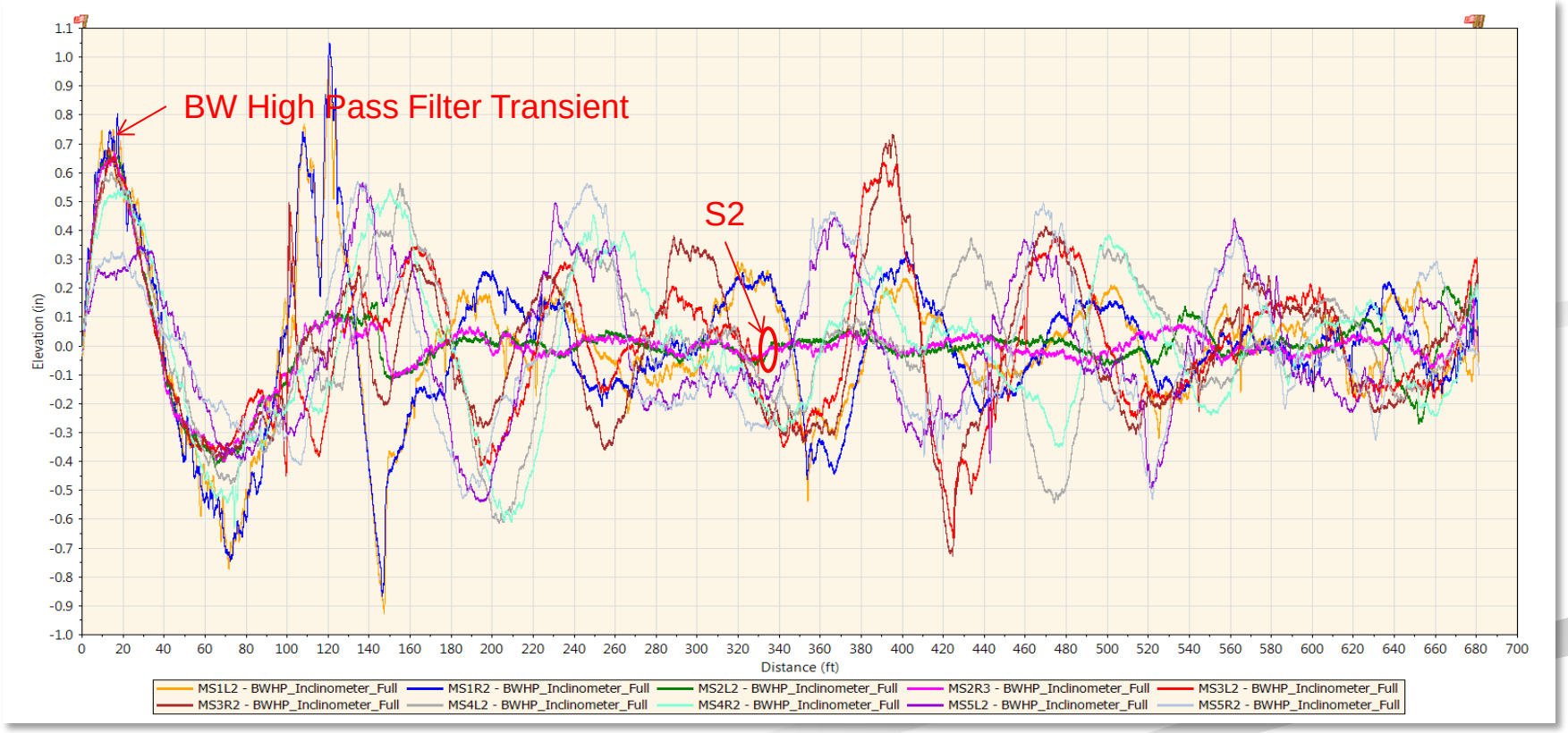
F_s = Force down slope = 2.5 lb force

Weight = 42 lb force

3.43°

S1-5 Filtered Profile Data

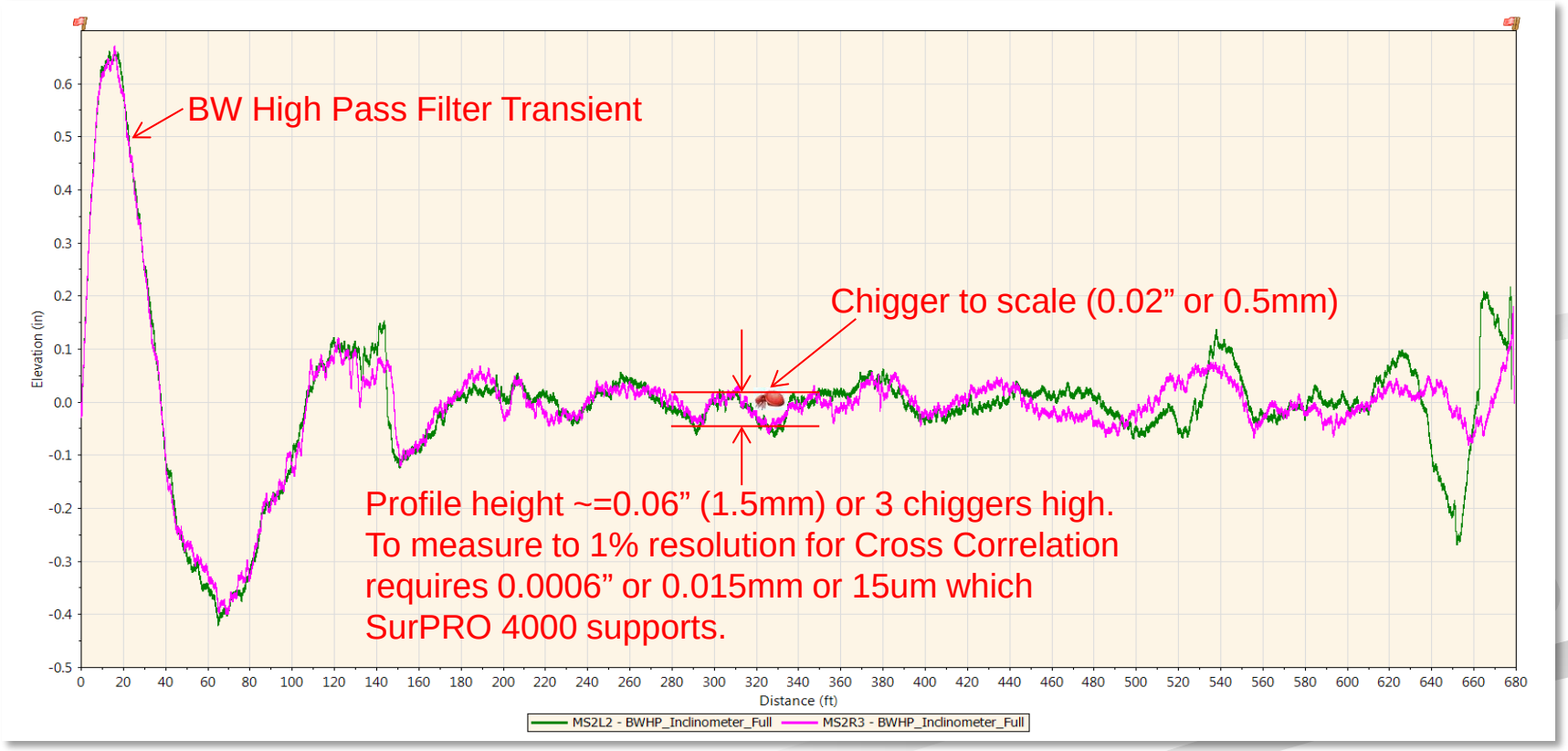
- MSDOT LWP and RWP after BW HP at 100 ft.



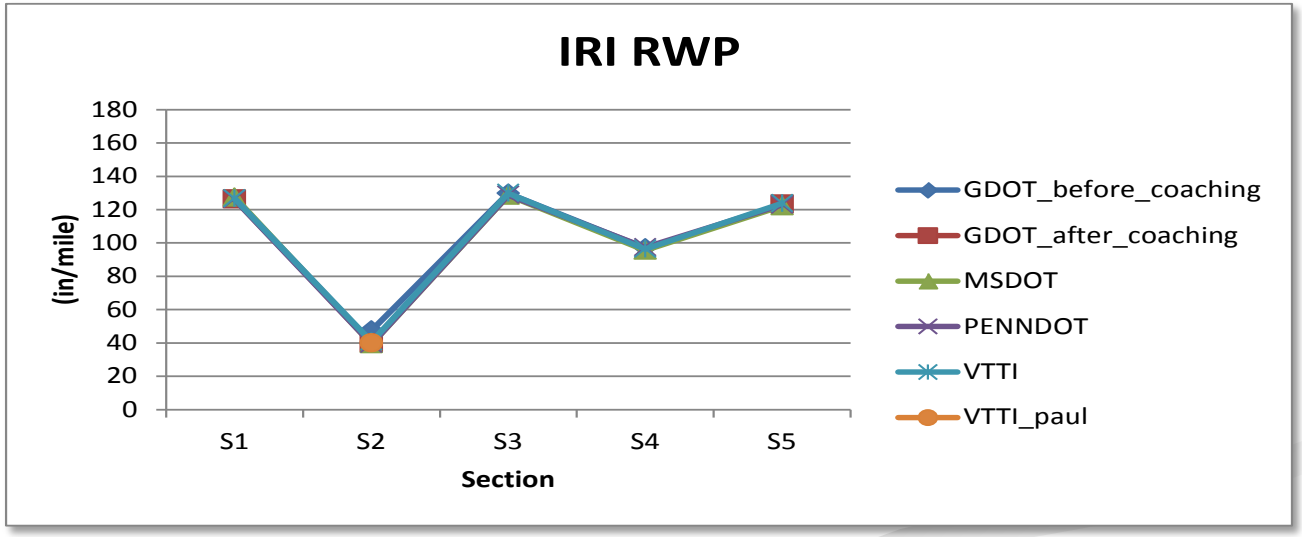

Beware
Of
Chiggers!
S2 RWP

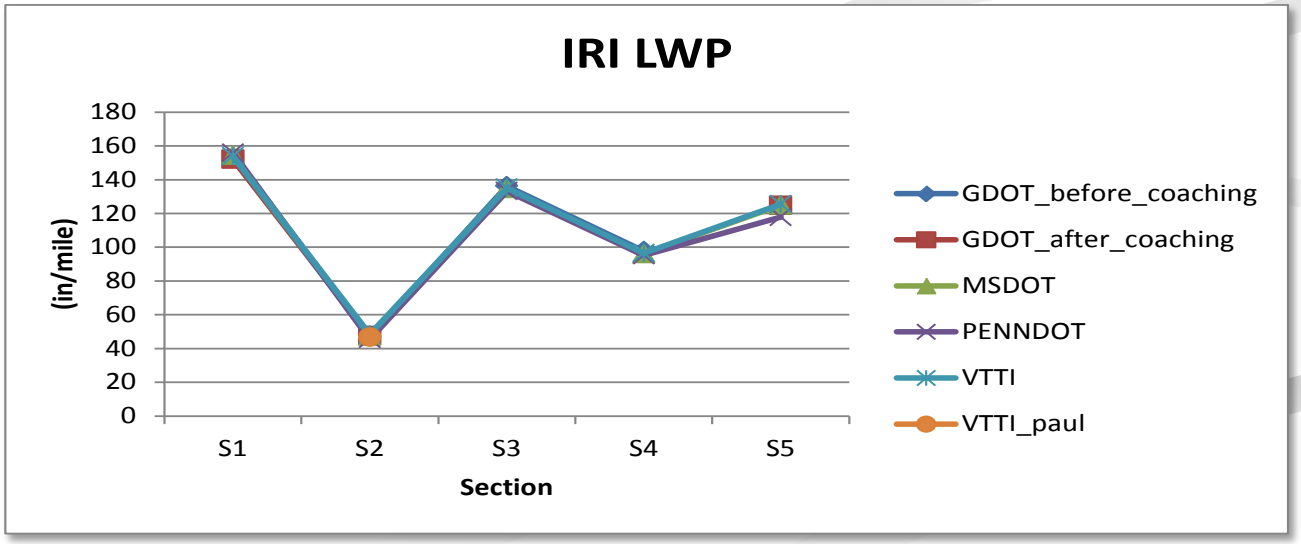
S2, Smart Road's Smoothest Pavement, IRI=40 in/mile

- MSDOT LWP and RWP after BW HP at 100 ft.



Analysis of Profile Data

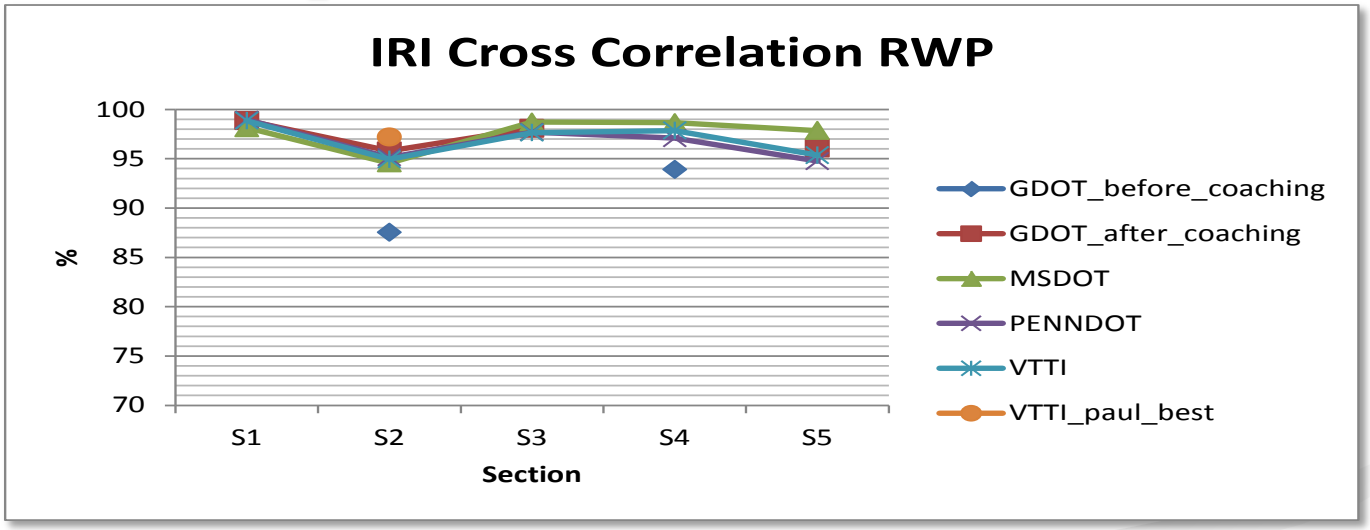


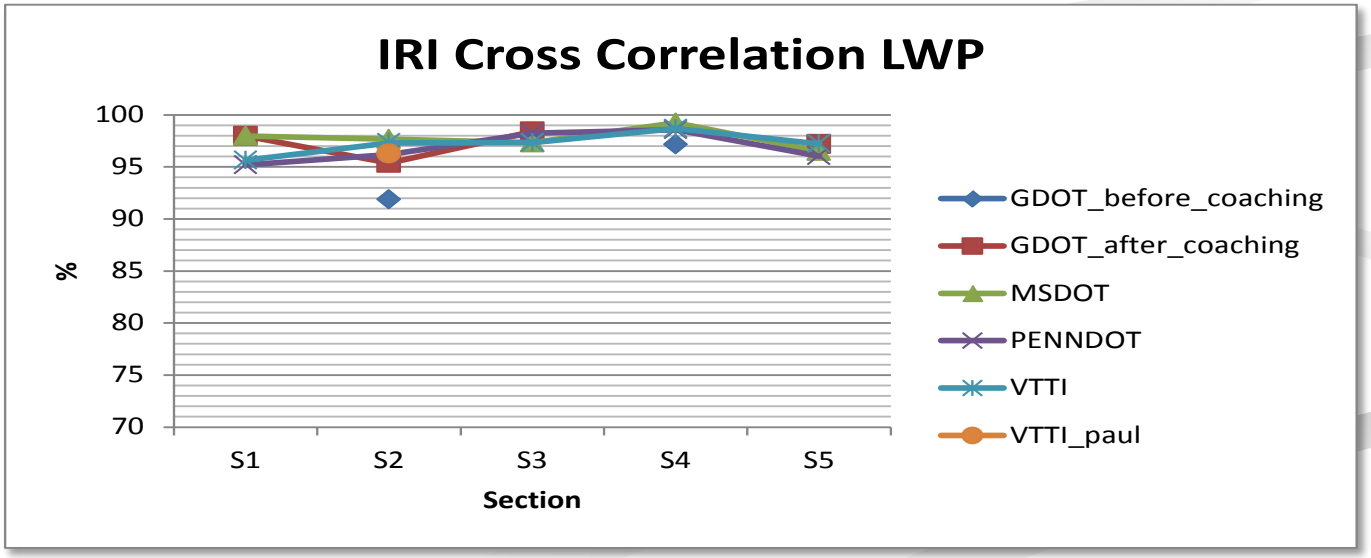


Coaching Operators

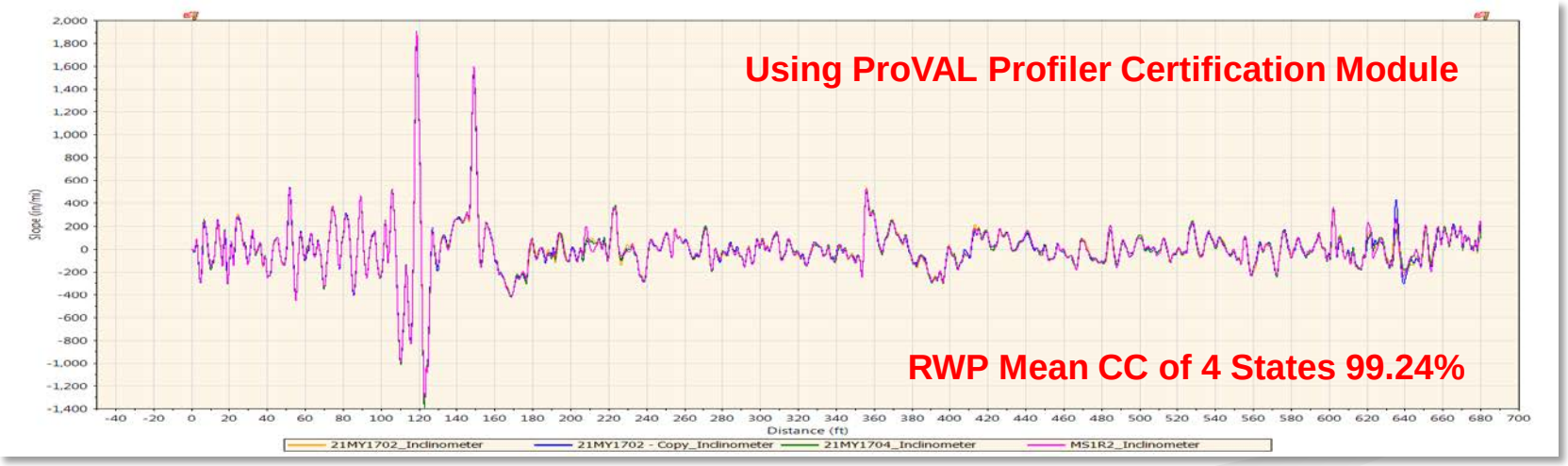
- Affect of handle position on S2

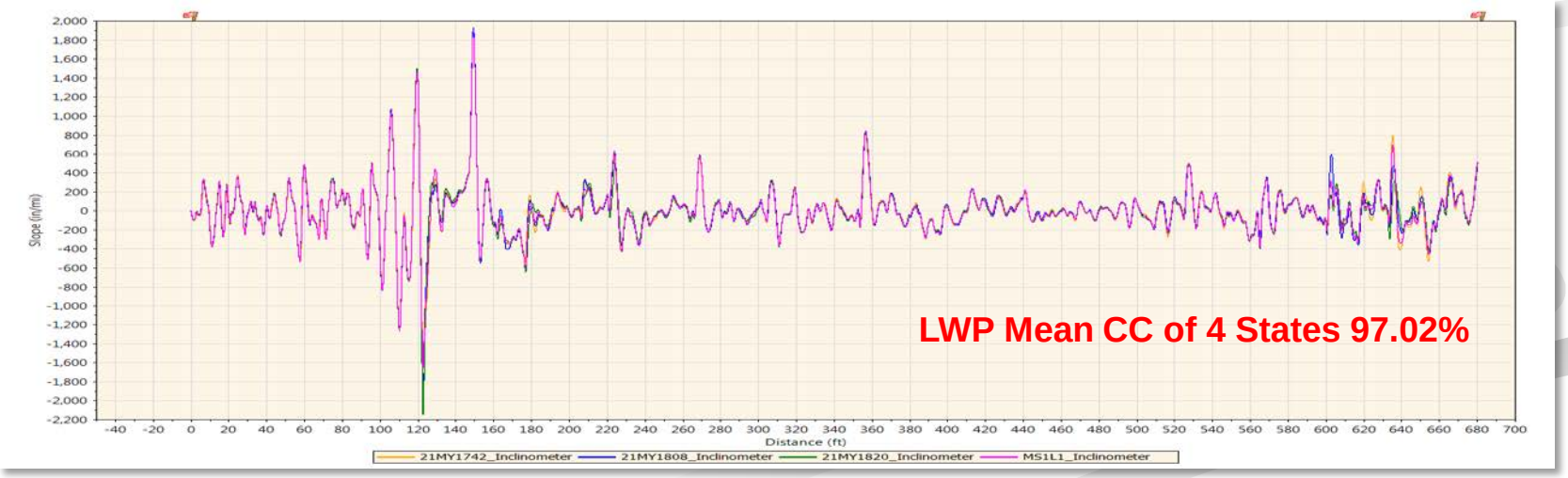
Analysis of Profile Data



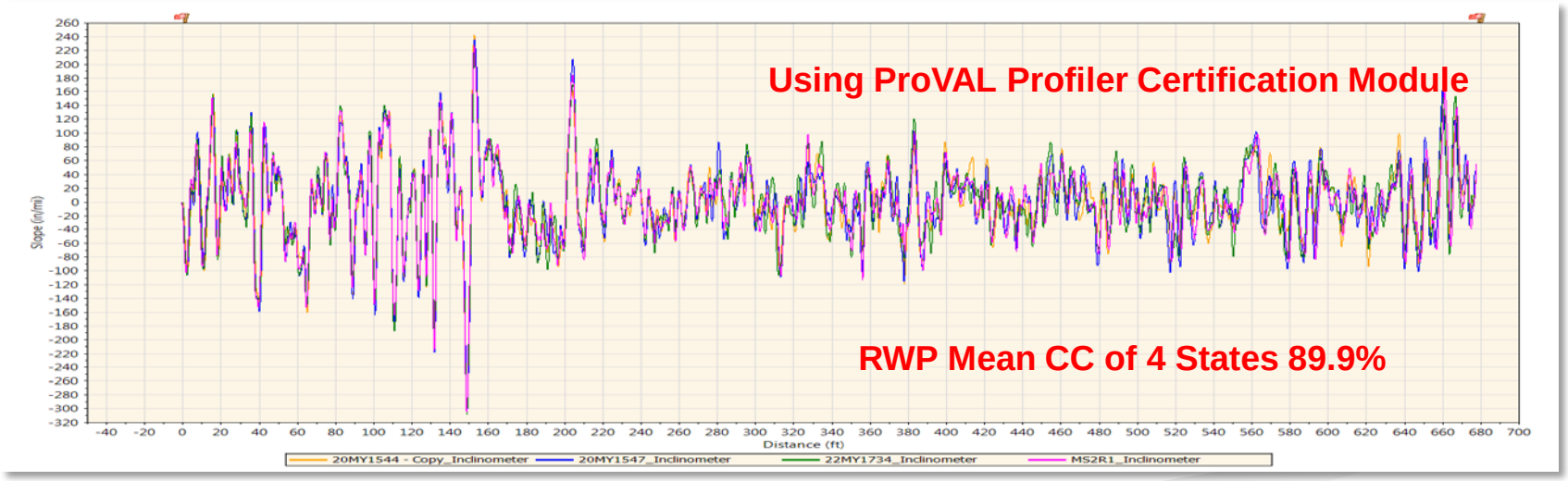


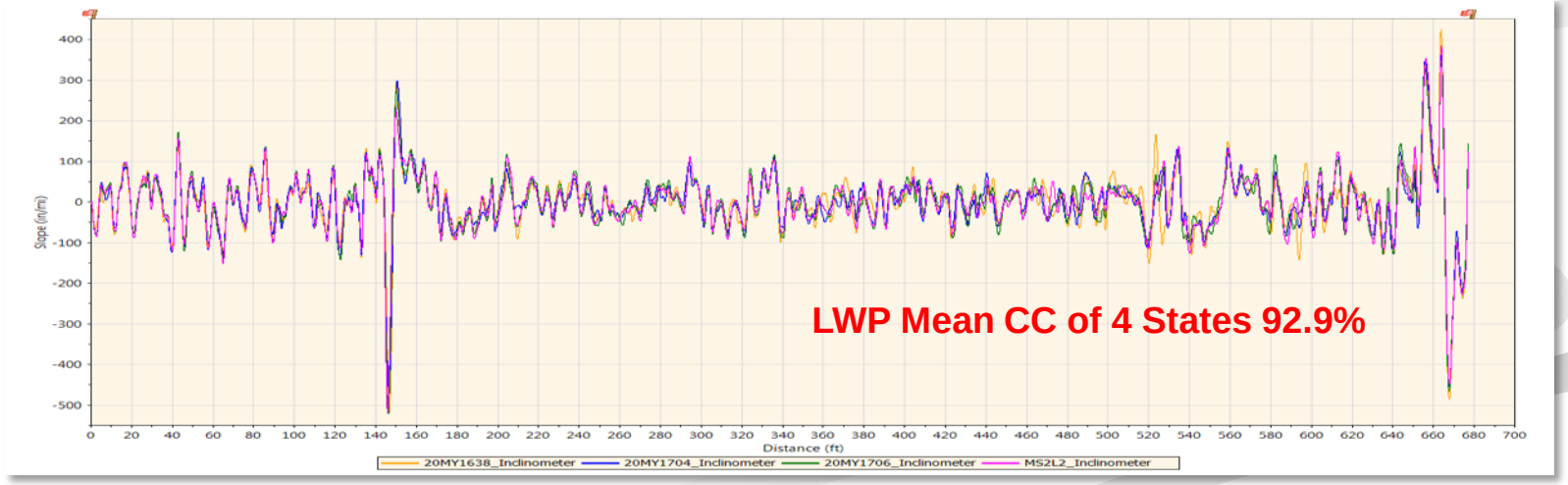
S1 Mean IRI CC for 4 States



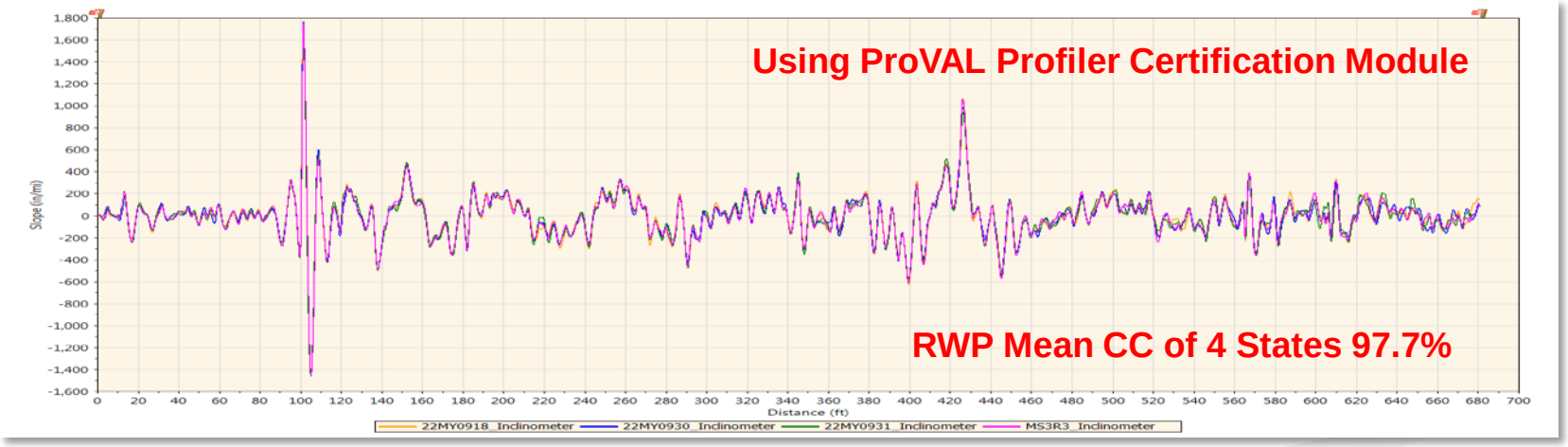


S2 Mean IRI CC for 4 States

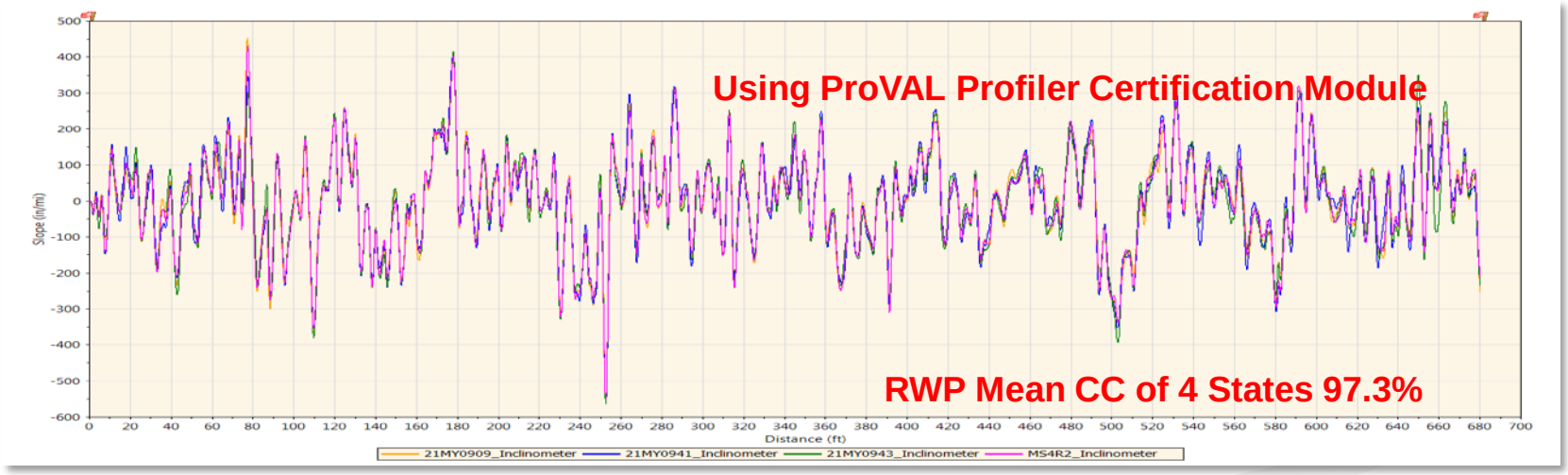




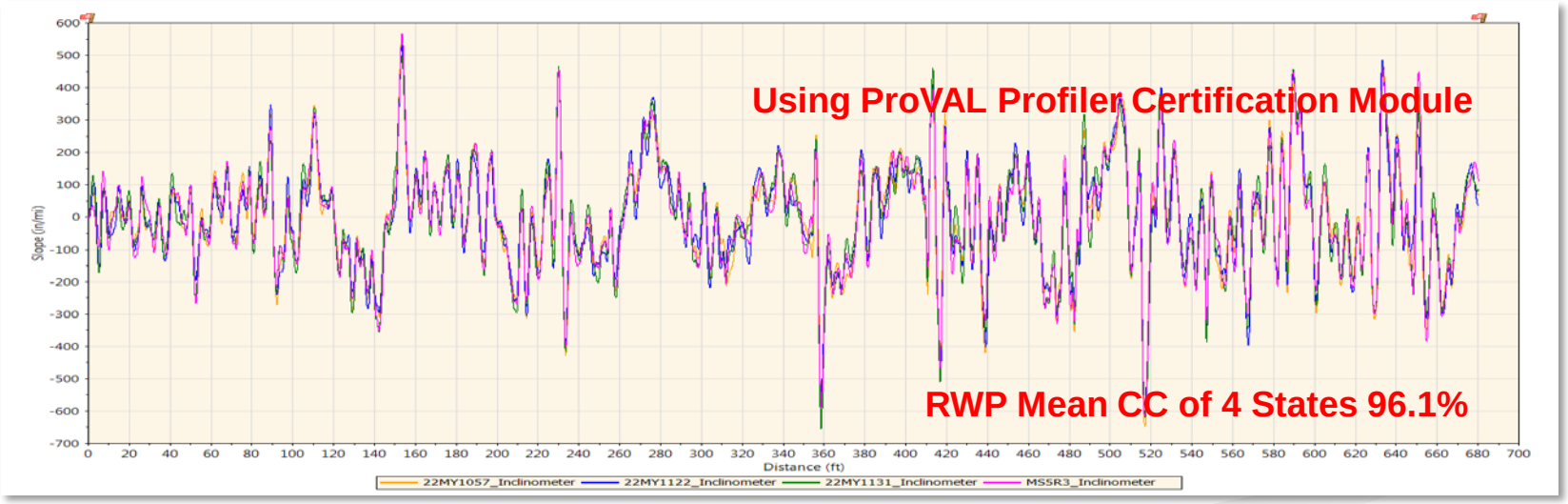
S3 Mean IRI CC for 4 States



S4 Mean IRI CC for 4 States



S5 Mean IRI CC for 4 States



Smart Road IRI Repeatability Cross Correlation Update

- After the Rodeo, by 2 operators alternating runs

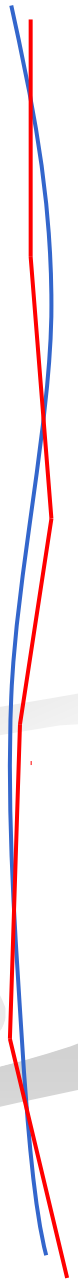
Section	Pavement Type	LWP	RWP
1	JRCP	99.0 %	98.9 %
2	CRCP, grooved	97.4 %	97.2 %
3	SMA-OGFC	98.5 %	98.4 %
4	SM 9.5	99.3 %	99.0 %
5	SM 9.5/12.5	97.8 %	98.3 %

Things That May Adversely Affect Cross Correlations

- DMI Error
- Tire Emulation
  - Effects of Pavement Texture—Tire Bridging Filter
  - Tire Footprint Width
- Vertical Measurement Resolution and Accuracy
- Data Filtering Issues
- FAILURE TO FOLLOW SAME PROFILE LINE! Error of 1 in. or more will adversely affect Cross Correlations

Cross Correlating with Inertial Profilers—Marking Wheel Path

- Mark a profile line that an Inertial Profiler can follow accurately at 50 MPH.
  - First temporarily mark offset from road edge to wheel path line at regular intervals—say 30 feet
  - Use ¼ " rope pulled tight or laser to define a "Best Fit“ of straight line through temporary marks—this will be line that can be followed by Inertial Profiler
  - Spray paint rope or snap chalk line on straight line
  - For driver visibility mark dots centered on line



Cross Correlating with Inertial Profilers—Steering

- Driver has Parallax Error viewing wheel path line—difficult to judge if on line
- Driver needs a Heads Up Display showing Low Angle View of wheel path
- If not already equipped mount a Low Angle video camera above wheel path laser
- Record camera video for later correlation with profiles

Observations & Conclusions

- Training of Operators was Successful
  - Learned new skill or improved skills for Reference Profiler configuration, calibration and operation
- Set up Certification Sites
- Good Agreement of 4 State DOTs Profiling Sections S1 to S5
  - Achieved mean IRI Cross Correlation of 4 Different SurPROs typically 97%

Observations & Conclusions

- Smart Road's Characteristics Presented Challenges for Profiling
  - Grade requires Reference Profiler operator to oppose component of Reference Profiler weight parallel to slope
- Smooth Pavement IRI Repeatability Cross Correlation
  - 97.2% on S2 RWP with IRI of 40 in/mile
- VTTI achieved 98-99% after the Rodeo

Thanks!

- VTTI and Staff
- GADOT
- MSDOT
- PENNDOT


Q&A

More Information

- www.surpro.com
- www.internationalcybernetics.com