SURFACE SYSTEMS & INSTRUMENTS

Profiling System Technology Developments

- Improvements to SSI Walking Profiler for generating reference profiles.

- LMI/Selcom RoLine sensor.
  - ►Evolution from prototype to production version.
  - ►Comparisons of Selcom RoLine sensor with Selcom single point sensors and three-in-line Acuity single point sensors.

- New hardware platforms for inertial profiling systems.

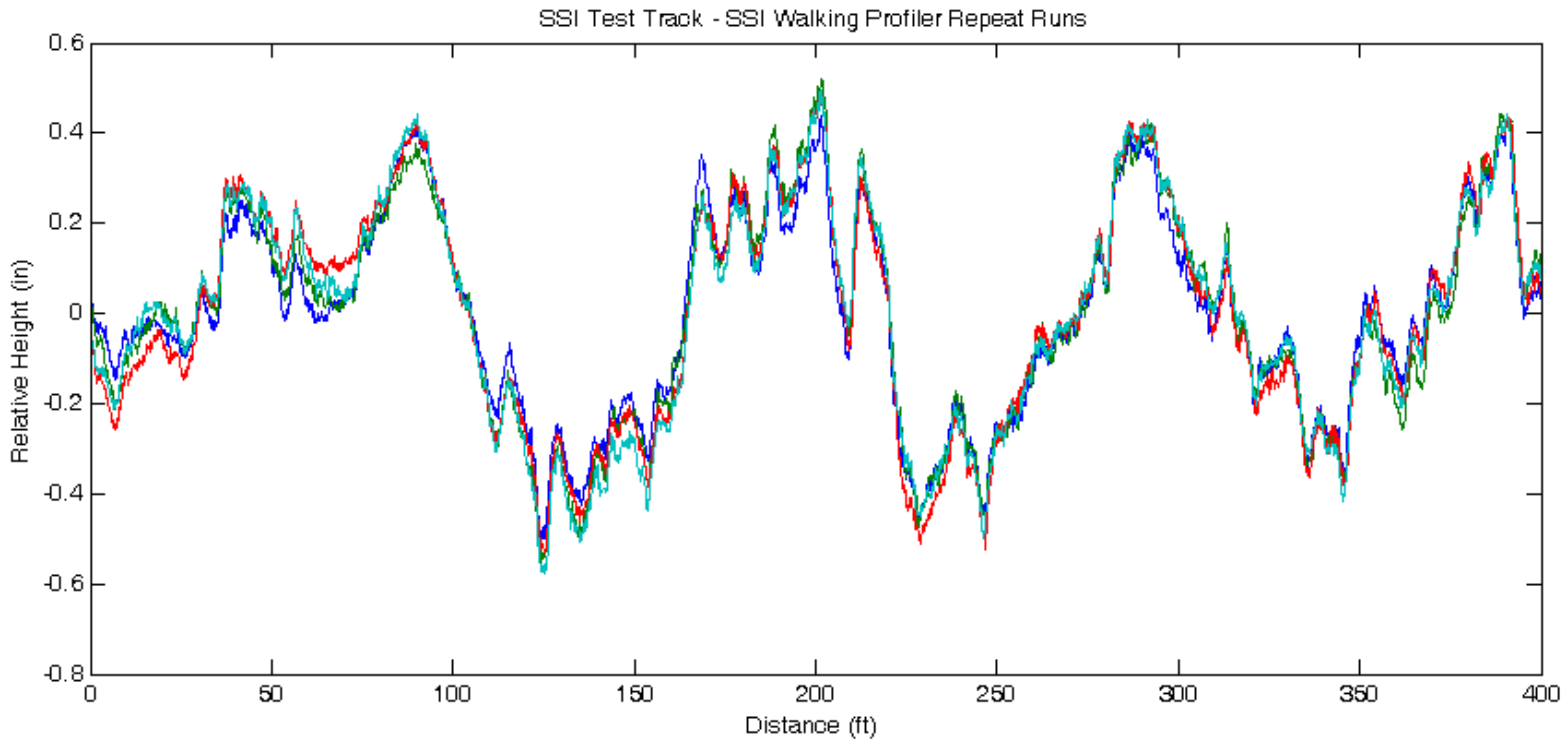
- Observations on the significance of proper accelerometer signal processing and integration.

SSI CS8800 Walking Profiler

- **Overview:**

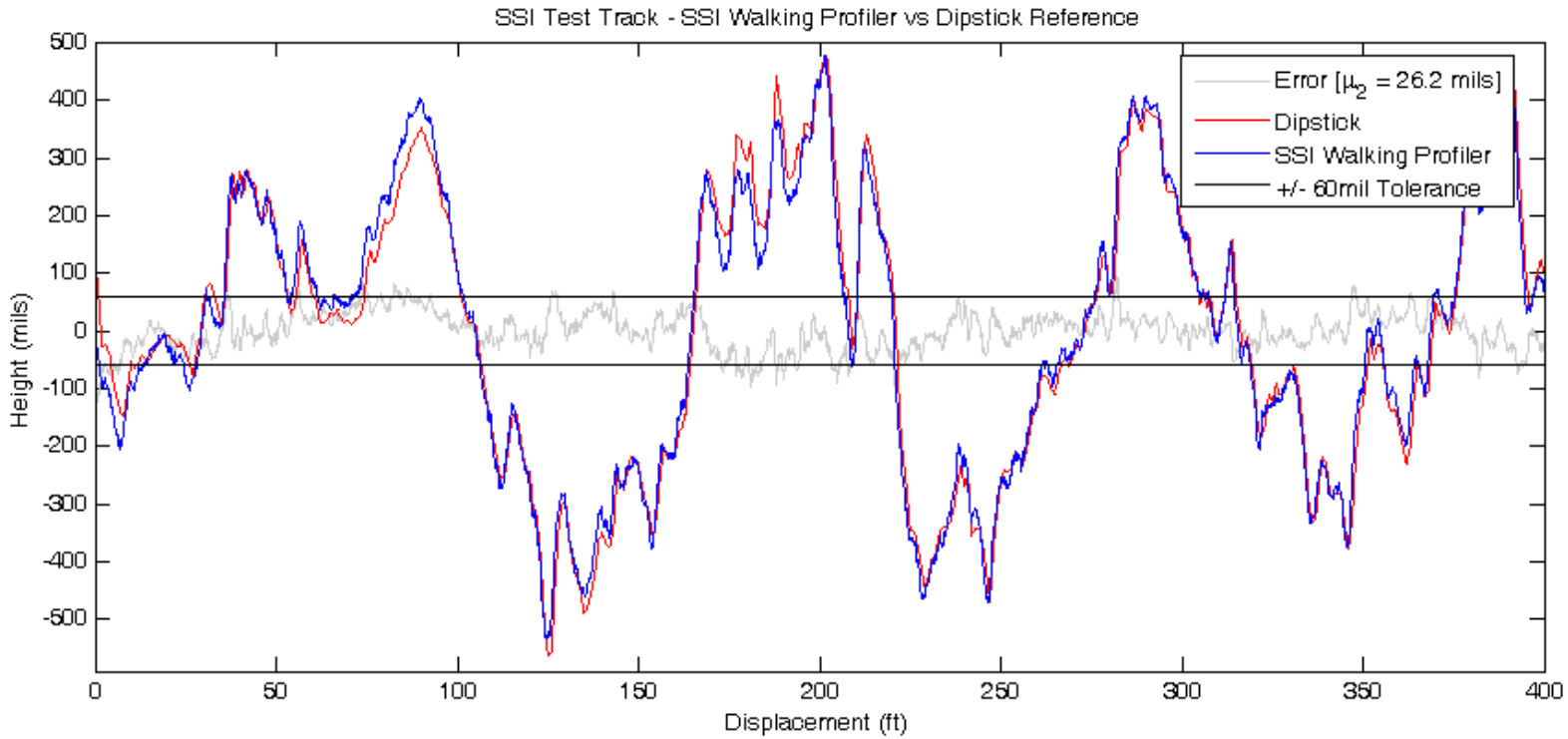
- Capable of collecting data with a true 1” sampling interval (vertical and horizontal).
- High and higher resolution modes of operation.
- Highest resolution for generating reference profiles for comparing inertial and other profiling devices.
- Cross-platform data analysis software for evaluating profiles of multiple devices.
- Integrated localized roughness templates and simulation routines.
- FF/FL outputs under development.
- Windows user interface programs on rugged wireless Toughbook computers.
- Optional RoLine sensor for wide footprint data sample and texture measurement.

SSI Walking Profiler--Repeatability



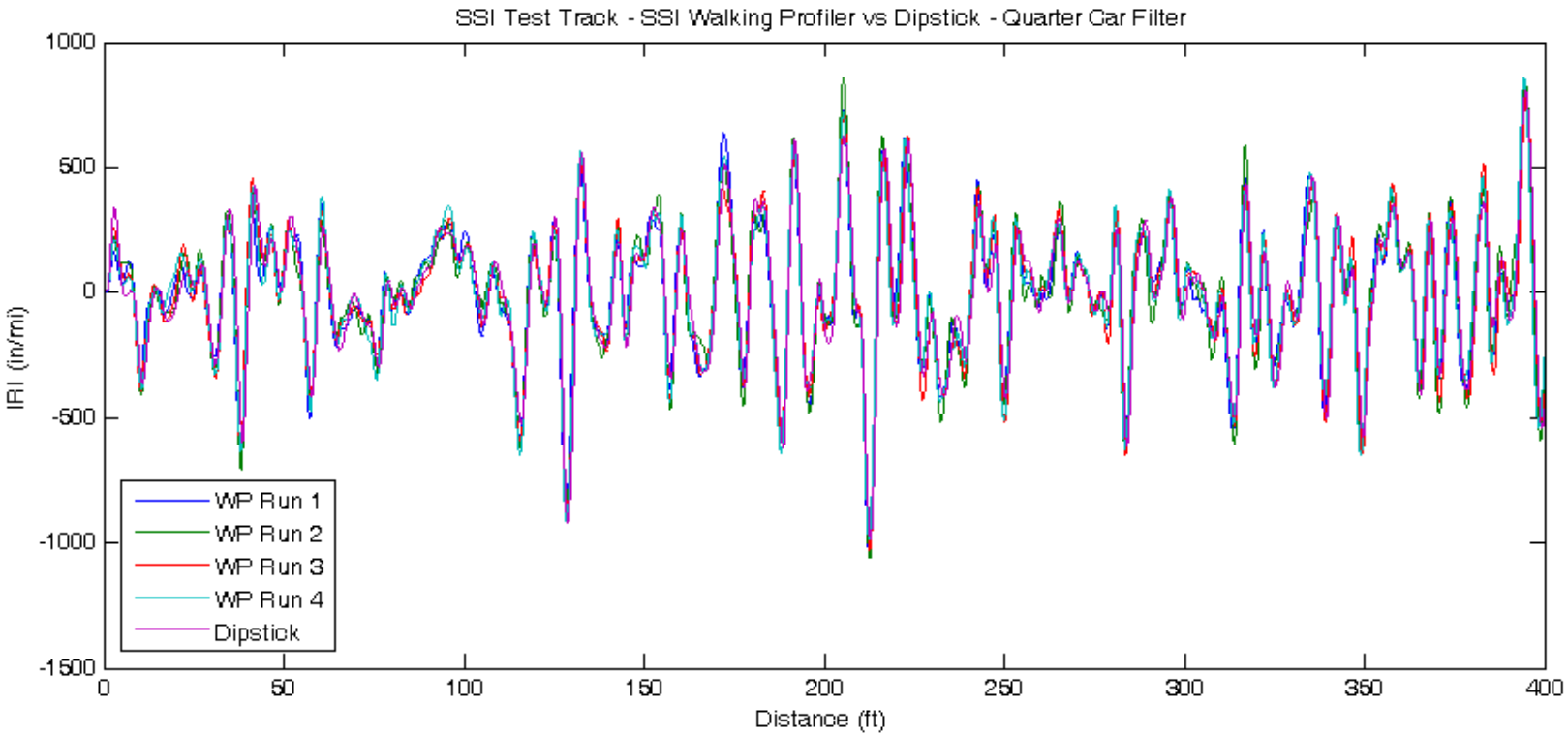
- Four repeat runs of the SSI Walking Profiler on Manhattan, KS control/calibration surfaces.

SSI Walking Profiler--Accuracy



- Texas style (Test Method 1001-S) evaluation of four repeat runs of SSI Walking Profiler vs. Dipstick.
- U2 Statistic: 26.2 mils
- Test surface IRI: 206

SSI Walking Profiler—Quarter Car

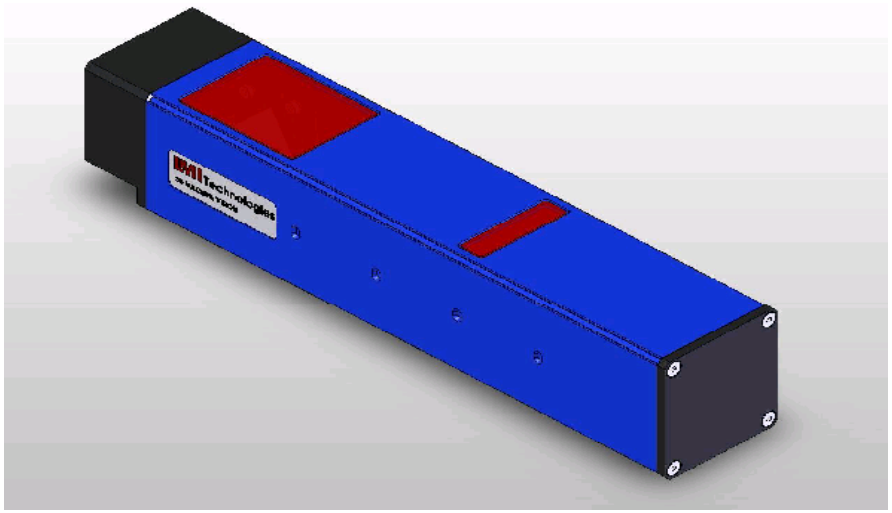


- Four walking profiler runs compared to the Dipstick after profiles processed with IRI quarter-car filter.
- Average-cross-correlation between WP runs and Dipstick: 90.3.
- Average-cross-correlation among WP runs alone: 85.9.
- Evidence that "repeatability" is not a prerequisite for accuracy.

Integration of Selcom RoLine Sensor

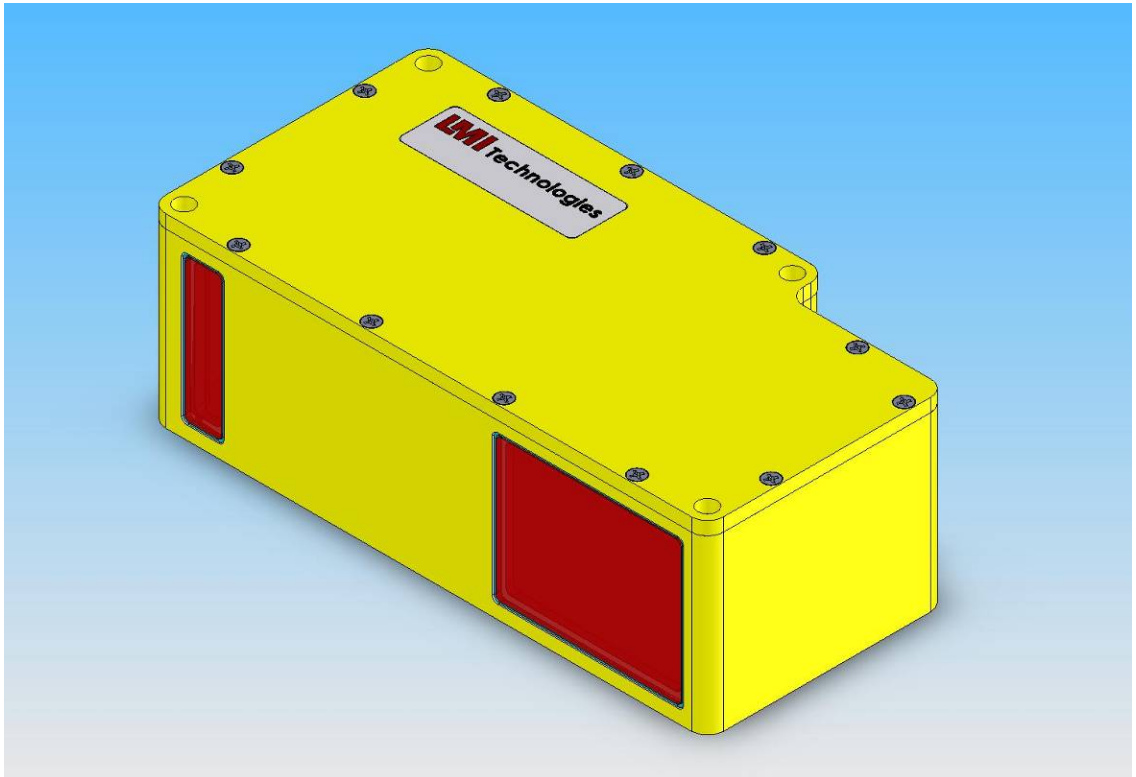
- *Background:* Selcom RoLine sensor was developed to address profiler limitations on concrete pavements with longitudinal tining, diamond grinding, and coarse textures.
- *2006 Objective:* Evaluate the performance of inertial profiling system instrumented with production RoLine sensor on various concrete pavements. Compare RoLine with (1) profilers with single point Selcom lasers and (2) profiling systems using three single point Acuity laser sensors (Ames “Triods” system).

RoLine Sensor Prototype-2005



- RoLine prototype hardware.
- Experimental version that has been substantially improved.

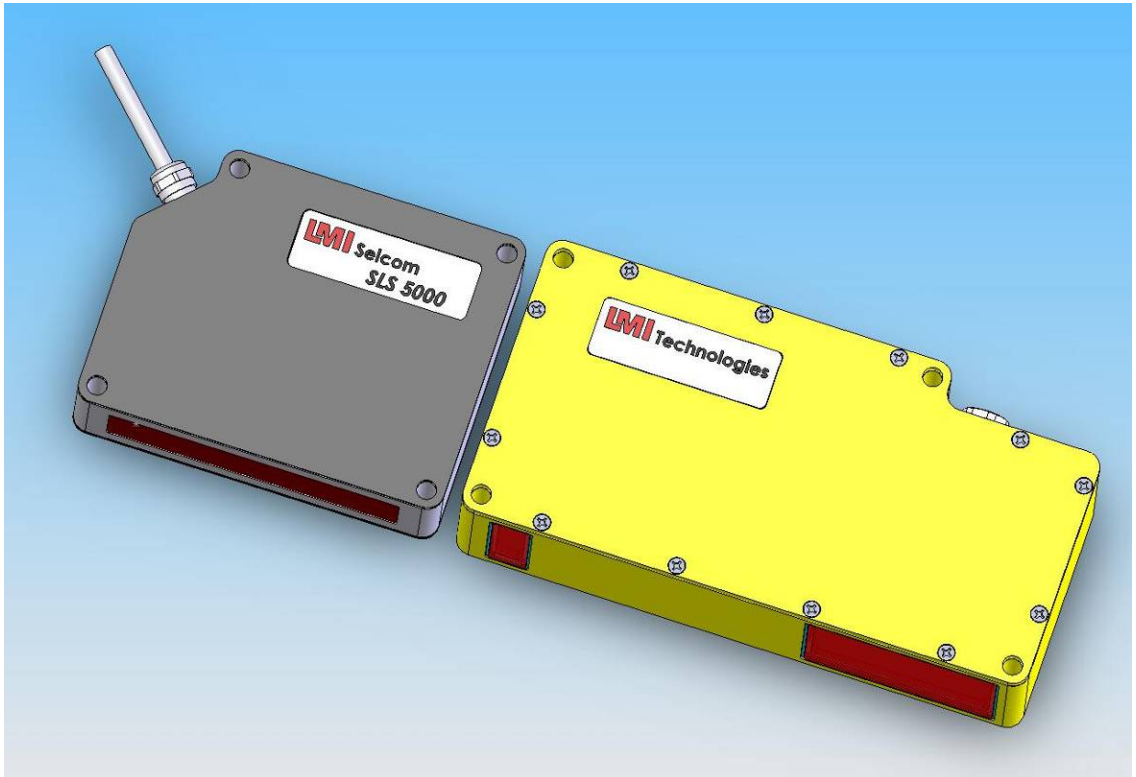
RoLine Production Version-2006



- **IMPROVEMENTS**

- Faster processor for increased sampling rate (faster profiling speeds)
- Improved optics (different laser, more powerful for asphalt & concrete)
- More stable form factor (Industrial mount instead of tube)
- Upgradeable (faster processor, firmware, etc.)
- Improved handling of sunlight

RoLine Production Version-2006



- **RESULT/ADVANTAGES OF IMPROVEMENTS TO SENSOR**

- Faster, better, more reliable, and consistent data,
- Upgradeable/Reprogrammable.
- Adjustable parameters (high rejection / low rejection).
- Manufacturers have flexibility to optimize use of laser scan points for road profiling applications.

Profiler Comparison on Iowa DOT Concrete Research Surfaces

Iowa DOT Hwy. 30 Concrete Research Sections

Section	Texture	Spacing	Depth	Pre-texture	Length	Stations
10	Diamond Grinding	---	---	None	59 m	141+72 to 142+31
205	Astroturf	Heavy Weight	---	None	169 m	142+31 to 144+00
Ia(B)	Long. Tine	3/4 inch	1/16 Inch	Astroturf	200 m	144+00 to 146+00
Ia(C)	Long. Tine	3/4 inch	1/8 inch	Astroturf	200 m	146+00 to 148+00
Ia(A)	Long. Tine	3/4 inch	1/16 inch	Burlap	200 m	148+00 to 150+00
Total					**828m**	**828m/2716.5ft**

Devices Evaluated and Testing Notes

►Profiling Devices:

- SSI LWP with RoLine.
- Iowa DOT 3 laser LWP (Ames “Triods” system).
- SSI LWP with single point laser.
- SSI High Speed profiling system with single point laser.

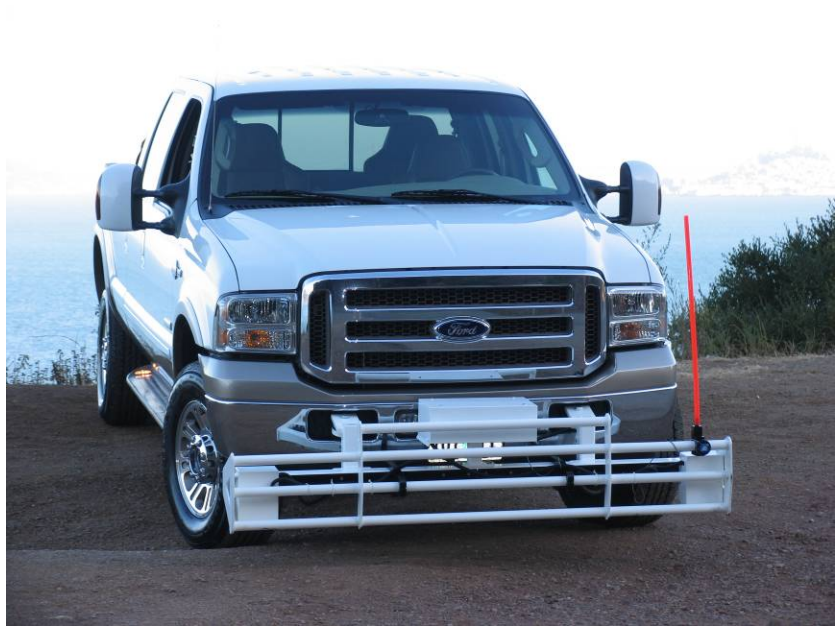
►Test Notes:

- Unmarked tracks, but recently paved surfaces
  - Intent: minimize lateral inconsistency that magnifies device tracking errors.
- Tracking aid used on Roline and 3-point LWP systems
- No Tracking device used on single point systems
- Collected 6 runs; used best 5 for analysis and comparison.
- Attempt to collect a 1390 ft. reference profile for accuracy assessment failed.
  - Dipstick malfunctioned
  - SSI Walking Profiler operated too fast due to time constraints.
  - 1390 feet excessive for a reference profile. SSI will attempt to collect a shorter section soon.

SSI LWP Test System Configuration

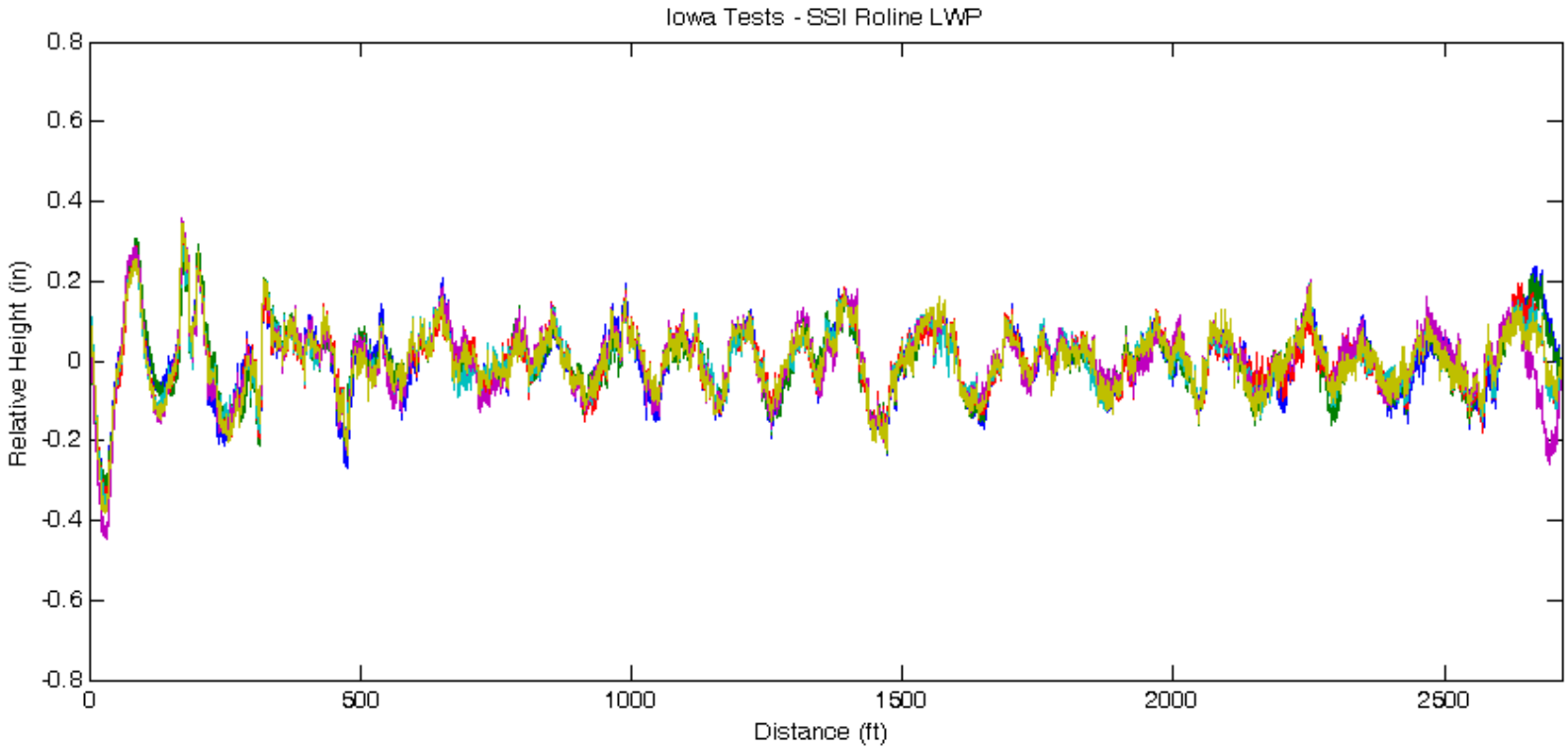
Mid-Vehicle Mounted Profiling System with RoLine sensor.	Same Vehicle with Single Point laser replacing RoLine.

More Test System Configurations



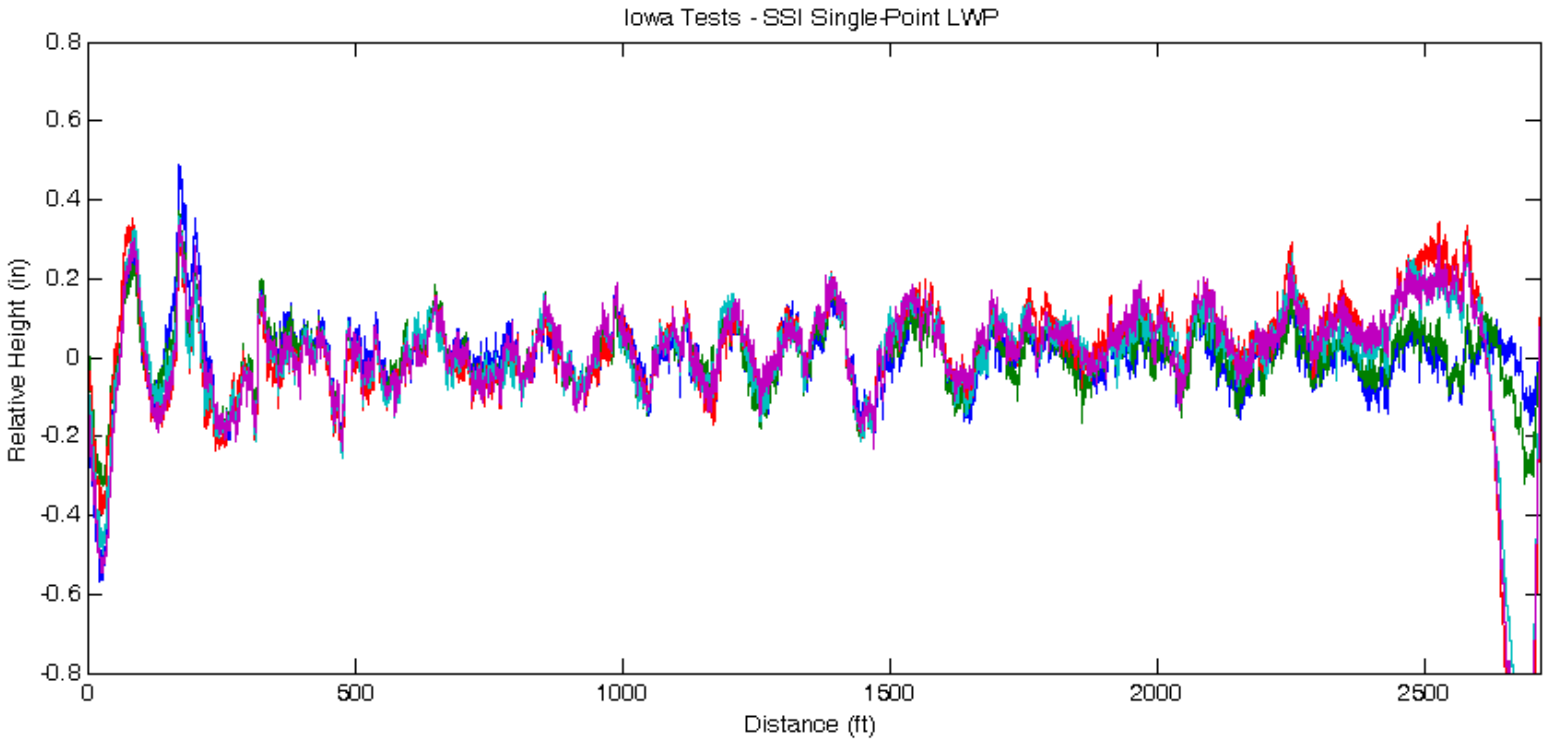
Iowa DOT Owned 3 laser LWP (Ames “Triods” system)	SSI HSP with Single Point Lasers.

SSI RoLine LWP



- Tex-1001-S Repeatability: 18.4 mils (< 35 is passing)
- Cross-Correlation (S.Karamihas method): 90.6
- IRI Mean: 89.34
- IRI Std Dev: 1.33

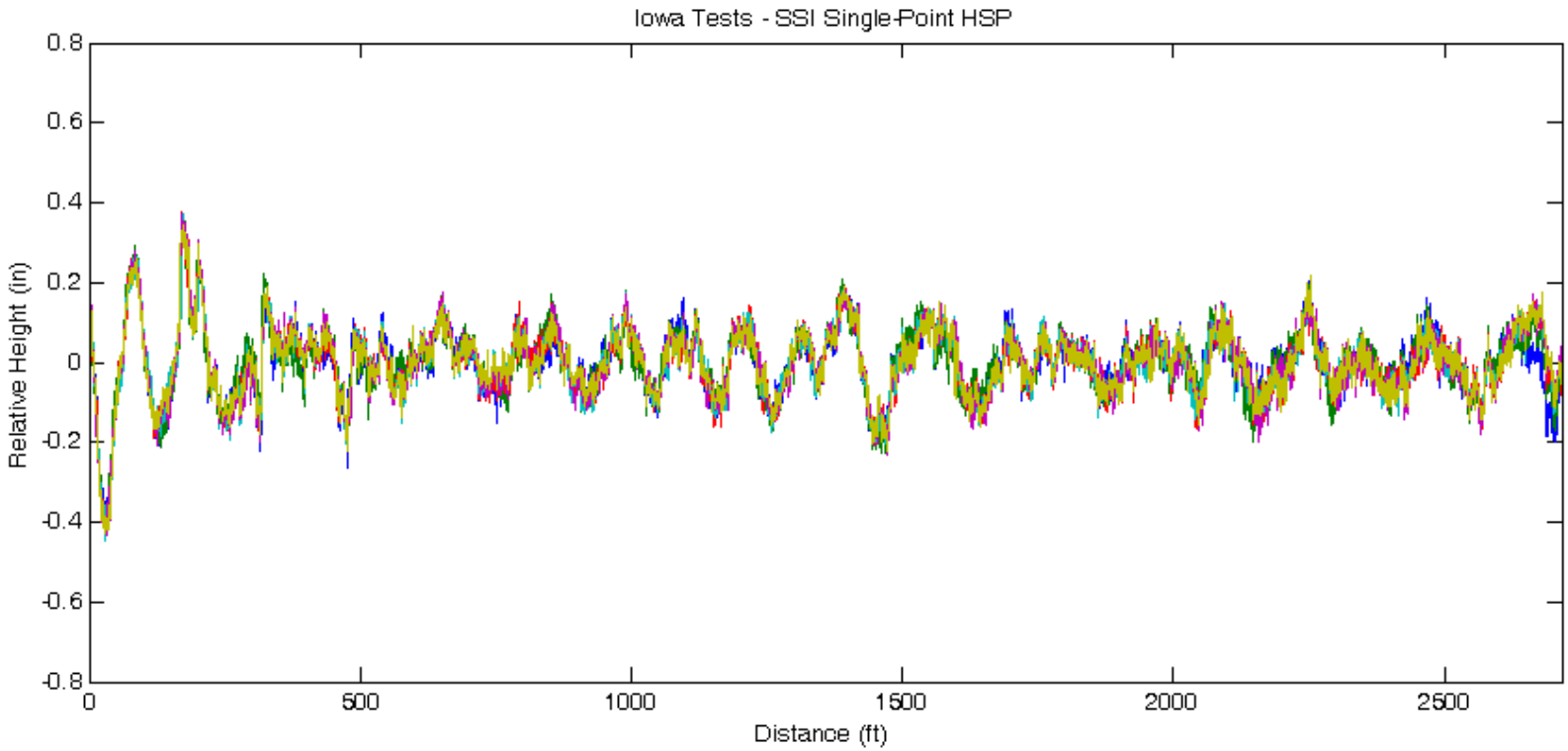
SSI Single Point LWP



- Tex-1001-S Repeatability: 47.5 mils** (< 35 is passing)
- **Ignoring the last 100 feet of data (which evidenced deviations from the lack of a tracking aid), the SSI Single-Point has a Tex-1001-S repeatability score of 26.1 mils.

  Cross-Correlation: 80.0
- IRI Mean: 92.88
- IRI Std Dev: 0.72

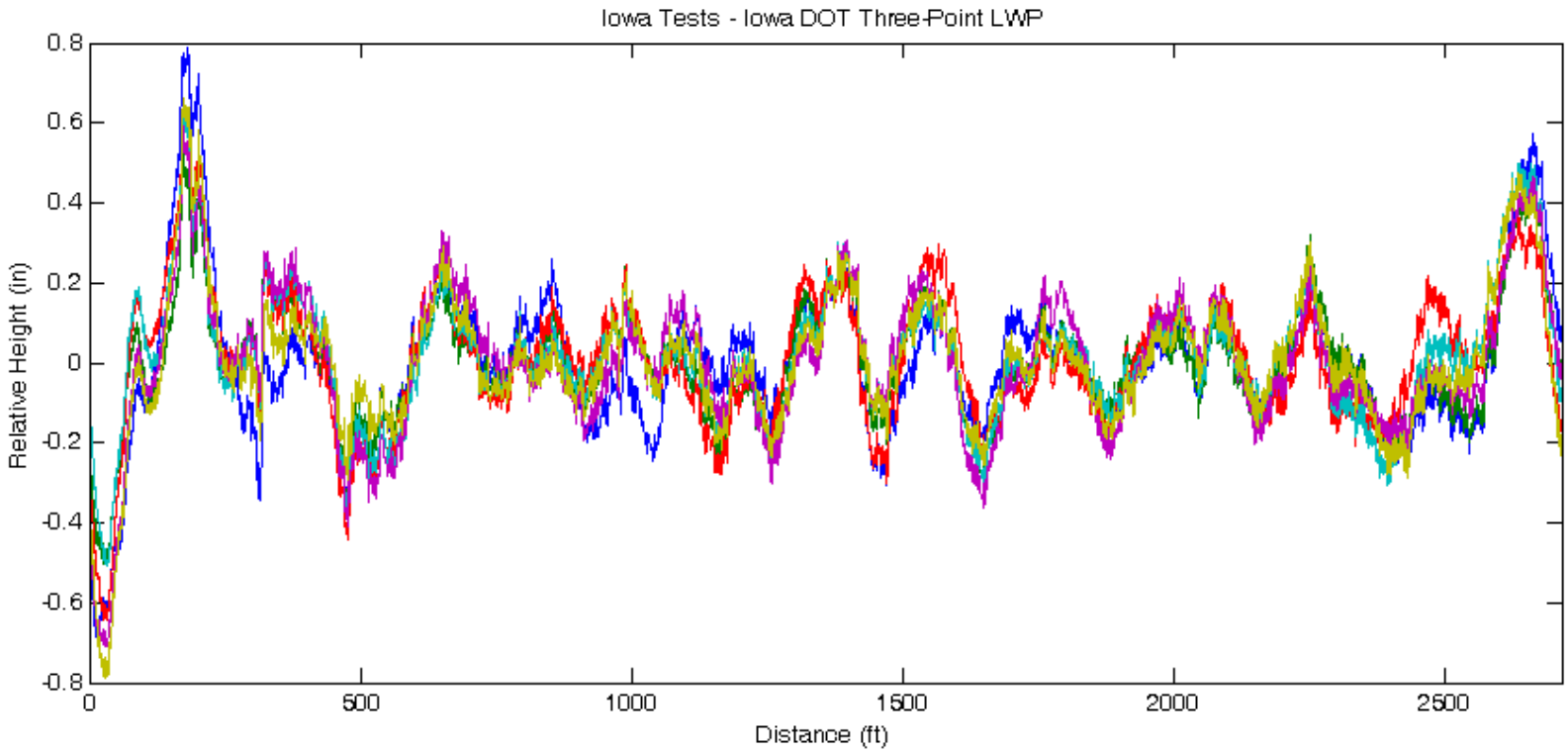
SSI Single Point HSP



SSI SLS5000 HSP

- Tex-1001-S Repeatability: 18.49 mils (< 35 is passing)
- Cross-Correlation: 77.9
- IRI Mean: 94.28
- IRI Std Dev: 2.75

Iowa DOT 3-Single Point LWP



- Tex-1001-S Repeatability: 57.8 mils (< 35 is passing)
- Cross-Correlation: 90.2
- IRI Mean: 89.45
- IRI Std Dev: 0.54

Summary of Results

Device	Repeatability			IRI (in/mi)	
	Tex-1001-S	Raw CC	Adj CC	Mean	Std Dev
SSI Roline LWP	18.44	92.3	90.6	*89.06*	1.44
SSI Single-Point LWP	47.48*	80.5	80.0	92.88	0.72
SSI Single-Point HSP	18.49	80.5	77.9	94.28	2.75
Iowa DOT Three-Point LWP	57.82	91.1	90.2	*89.48*	0.59

Notes:

►Tex-1001-S Repeatability is in mils and must be below 35 mils to pass.

►Raw CC is the average raw correlation coefficient of the quarter-car filtered data.

► Adj CC is the average standard-deviation-adjusted correlation coefficient of the quarter-car filtered data.

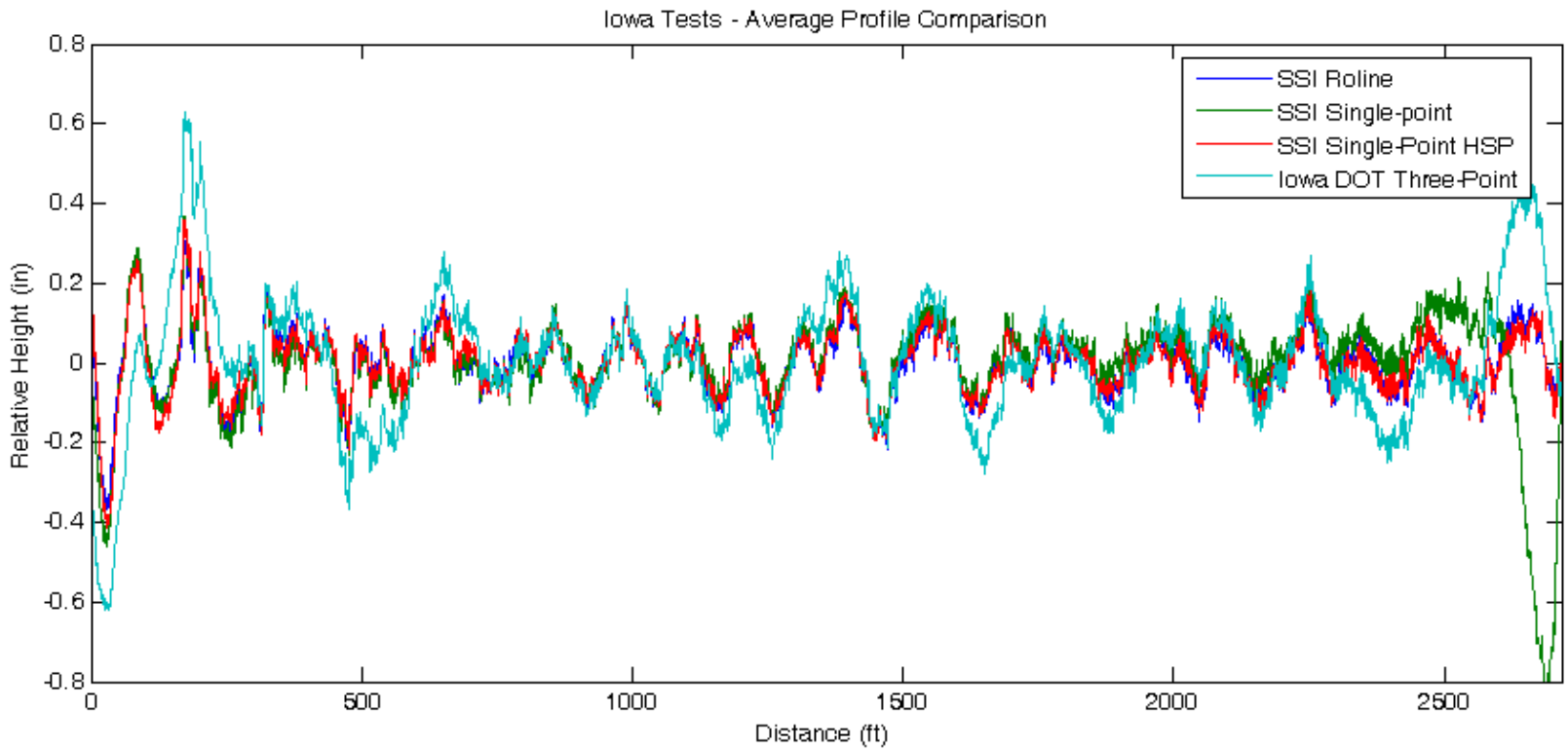
► The Adj CC values are have no profiler "synchronization" (sliding) was applied. All lengths were normalized to the known length of the track.

► IRI standard deviation must be below 3.0 in/mi to pass Tex-1001-S specifications.

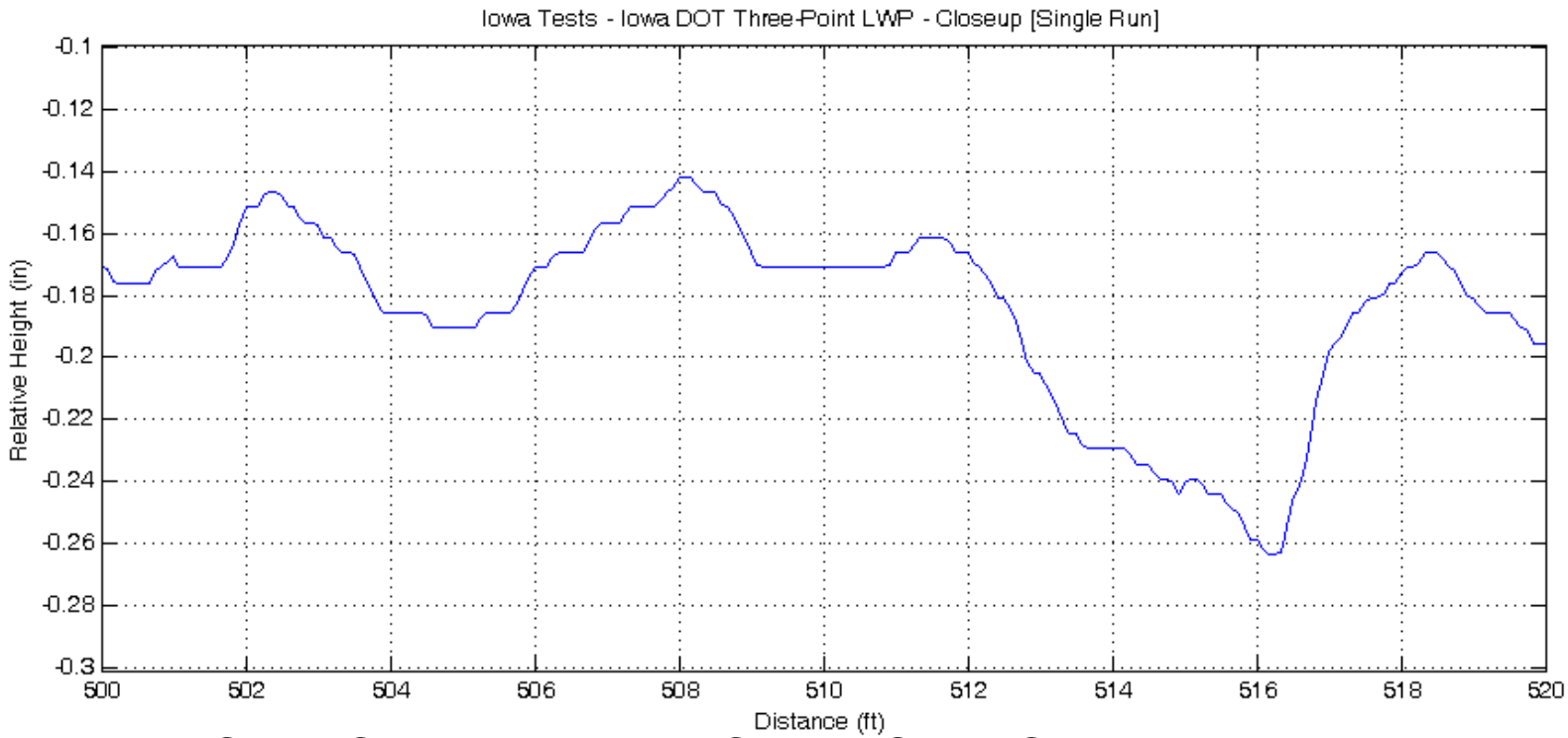
► *Ignoring the last 100 feet of data (which evidenced deviations from the lack of a tracking aid), the SSI Single-Point has a Tex-1001-S repeatability score of 26.1 mils.

► The SSI Roline and Iowa DOT devices used tracking aids, the SSI Single-Point devices did not.

Overlay of Traces from All Devices

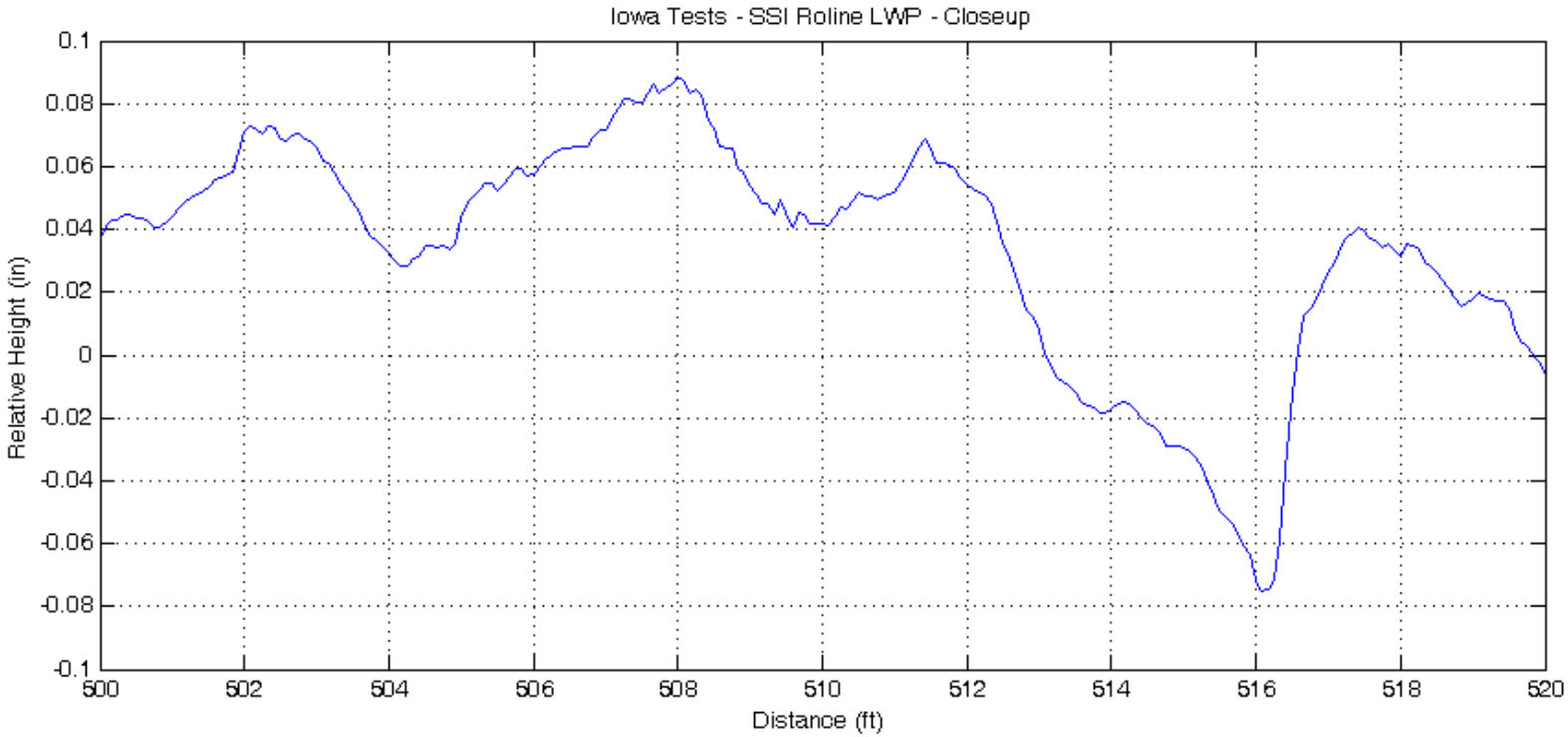


Close-Up Inspection of Profile Trace From Iowa LWP Displays Suspicious/Artificial Attributes



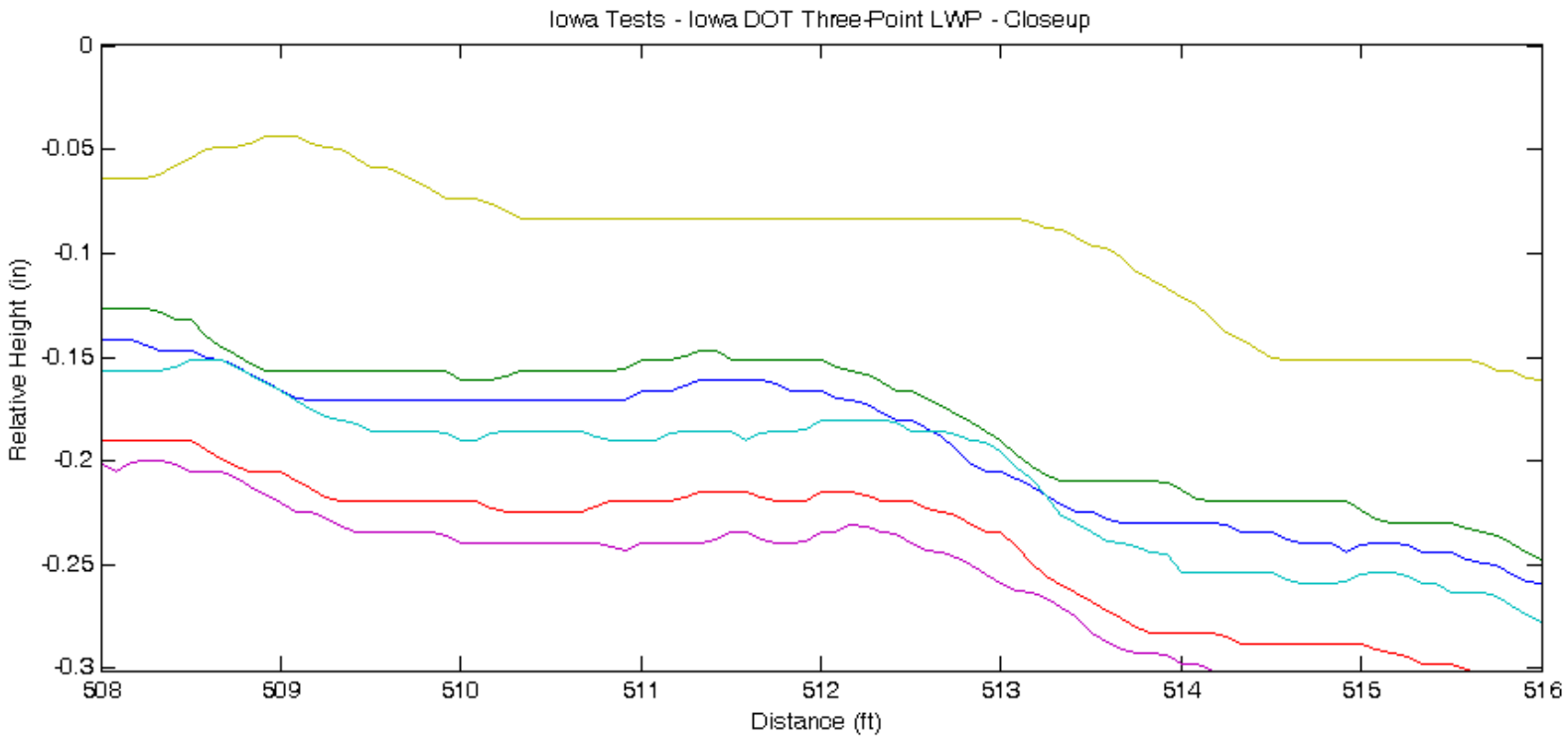
- Graph of 20ft section of profile from Iowa DOT 3 laser LWP (one run only).
- Question: Are flat spots actually on the surface?

SSI LWP Profiler Lacks Suspect Attributes



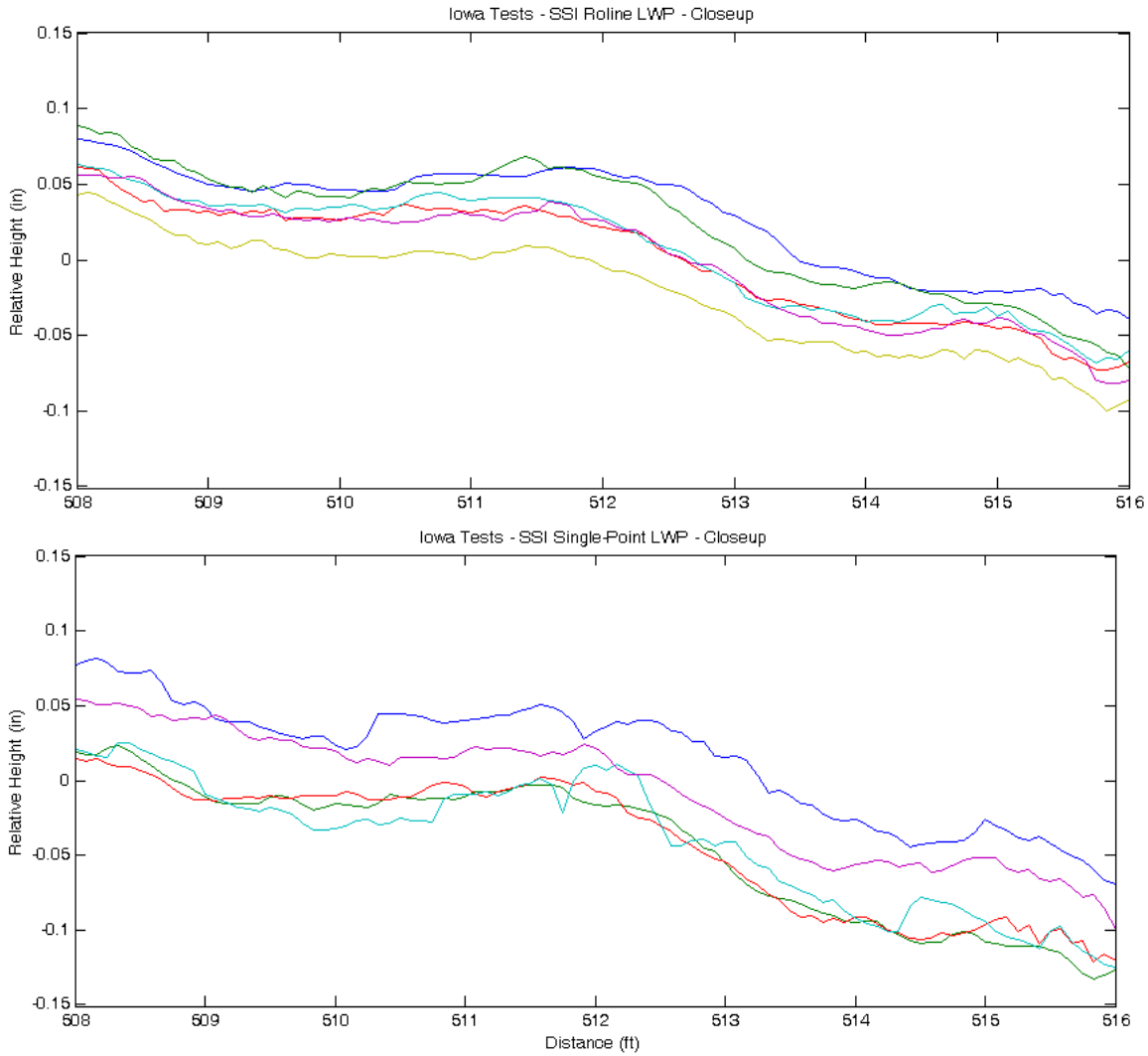
- Graph of same 20ft section of profile from SSI RoLine LWP (one run only).
- No flat spots or artificial attributes.
- Intent/Requirement: collect valid sample of the pavement at one inch intervals.

Iowa LWP Has Suspect Attributes in Profile (cont).



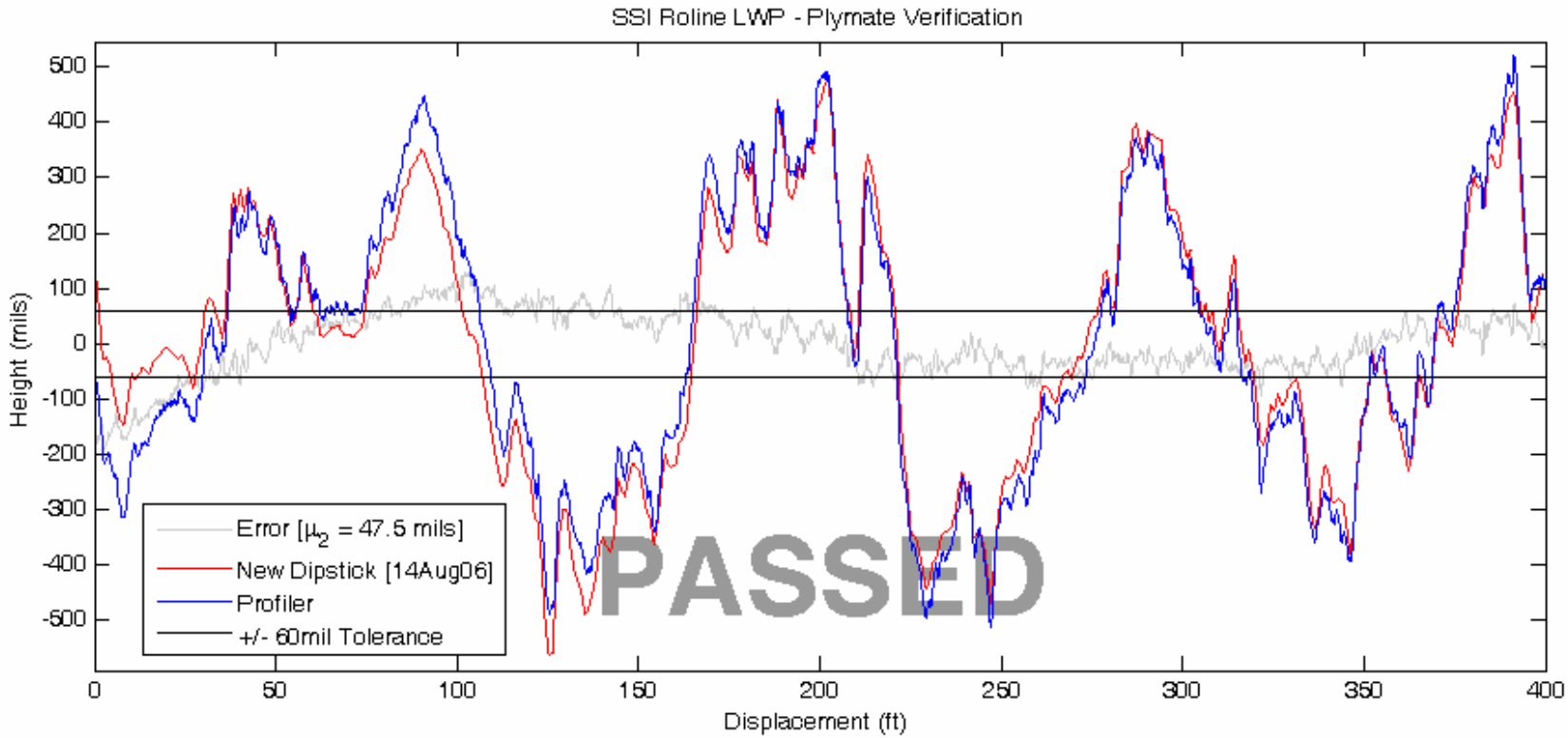
- Close view of overlay of 6 collections with Iowa DOT 3 laser LWP over same 8 ft.
- Flat spots raise suspicion of whether Iowa LWP is reporting what is actually on the pavement.
- Unlikely that there are 2-3 ft. ***perfectly flat*** sections.
- The “square/blocky” attributes could evidence a median filter (possibly as long as 36”) is being applied to the relative height data from the Iowa LWP.
- This same device has passed certain repeatability tests with flying colors, but it may be doing so with a certain level of disregard for what is actually on the surface.

Zoomed Profile of SSI LWP Does Not Display Suspect Attributes



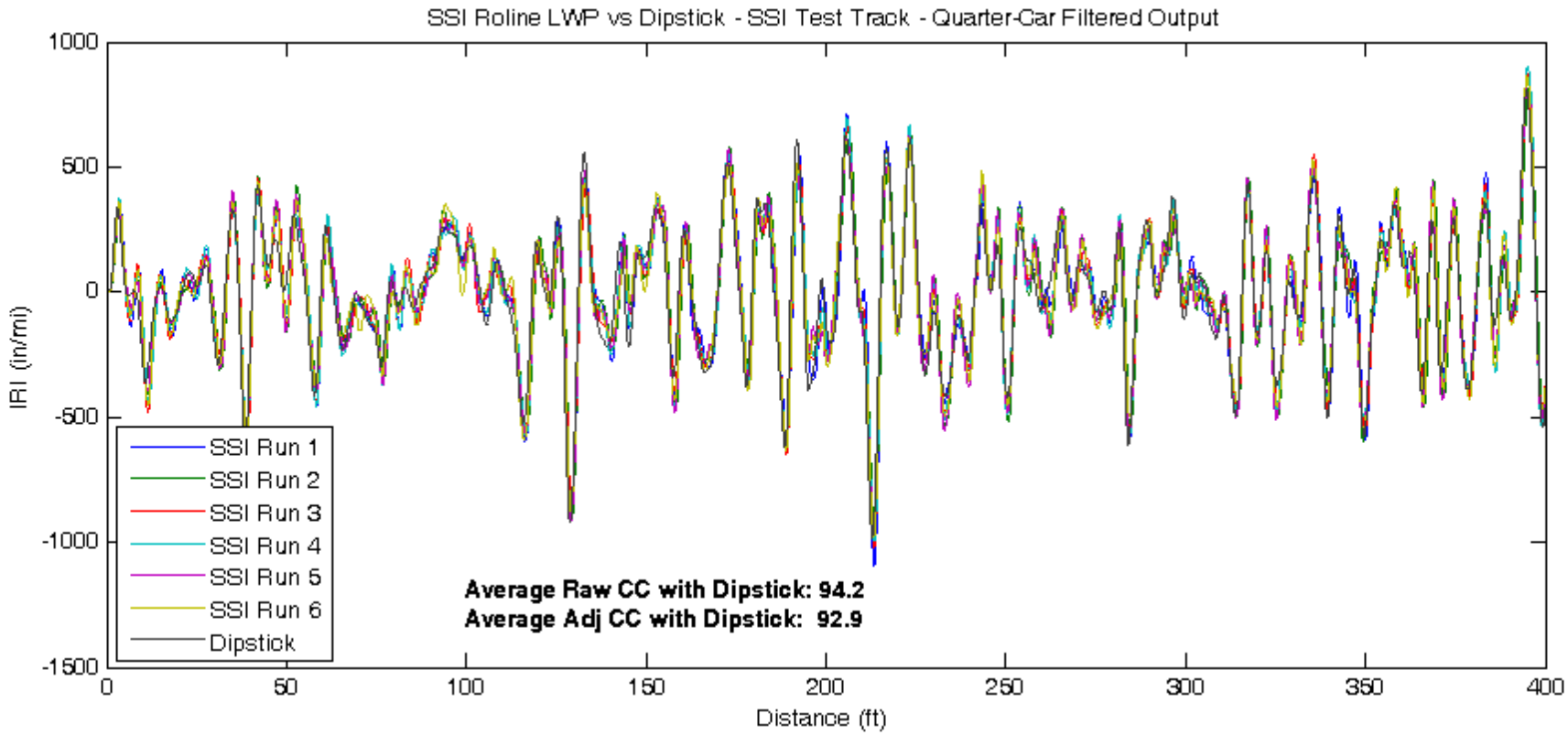
- Close up SSI RoLine and Single Point LWP profiles over same 8 ft. section.
- No flat spots or artificial attributes with either SSI LWP (RoLine or single point).

SSI RoLine System—Accuracy Validation



- SSI RoLine LWP Used for Iowa Tests Validated for Accuracy Under Texas Style Comparison with Dipstick on Kansas Calibration Site.

SSI RoLine System—Accuracy Validation

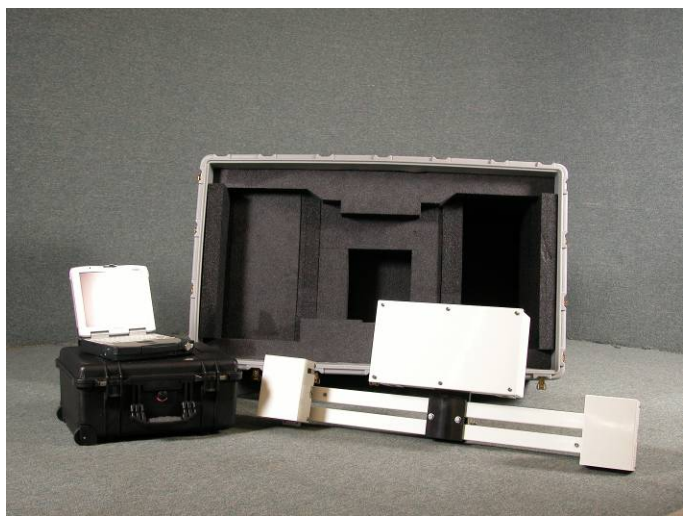


- Additional SSI RoLine Accuracy Verification: Cross-Correlation Comparison with Dipstick: 94.2

Profiler Comparison Conclusions

- Selcom RoLine sensor achieves anticipated improvement in profile testing on concrete surfaces.
- SSI RoLine demonstrated at least equivalent performance to Iowa LWP under benchmarks of repeatability and cross-correlation.
- Iowa LWP device generated profile with suspect attributes that were not detected by repeatability assessments.
- Evaluating accuracy is essential to assess overall profiler competence.

New Hardware Platforms for Inertial Profiling Systems



►True Portable Profiling System.

- RF Transmission of profile data.
- Requires only a 2” receiver and standard 12V power supply..
- In-cab enclosure with operator computer and printer (AC/DC powered)
- Reusable shipping container

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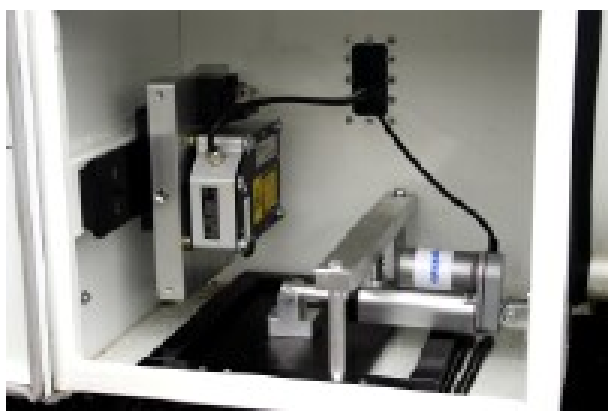
New Hardware Platforms for Inertial Profiling Systems (cont.)

►Integrated Mid-Mount Profiling System.

- Profiling system modules embedded into stable/protected location vehicle.
- System placement reduces accelerometer motion and associated issues.
- Linear actuators shelter components when system idle.



New Hardware Platforms for Inertial Profiling Systems (cont.)

►Multiple Purpose Profiling System.

- Functions as lightweight or high speed profiler.
- Custom trailer hardware designed specifically for profiling applications.
- Adjustable air suspension, independent each side.
- Self-contained: dependency on tow vehicle limited to 12V power supply.
- RF wireless radio transmission of profile data.

SURFACE SYSTEMS & INSTRUMENTS

- Questions?
- Next: Accelerometer Issues