

CS8800 WALKING PROFILER

2015 RPUG

Raleigh, NC

4 November 2015



Overview

- CS8800 Design Evolution
- Benchmark v. Reference Profiler Experiment
 - 2015 vs. 2013 Performance
- Ongoing Refinements
- Collateral Benefits of CS8800 Reference Profiler Development

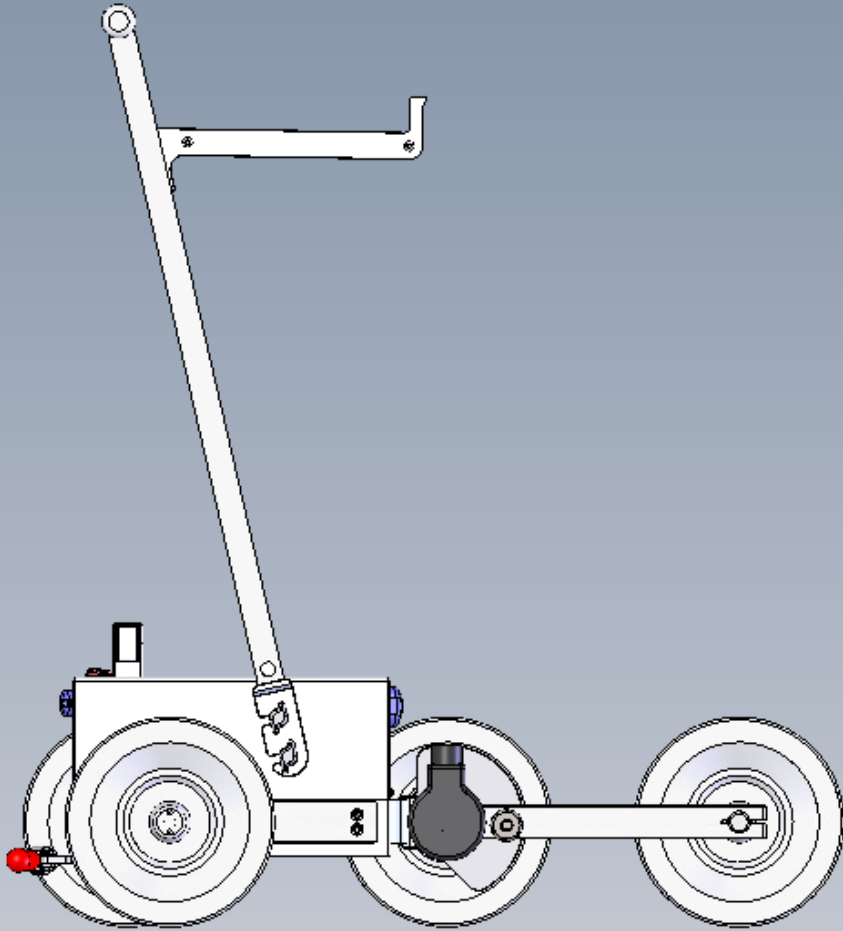
CS8800 (V1-2003)



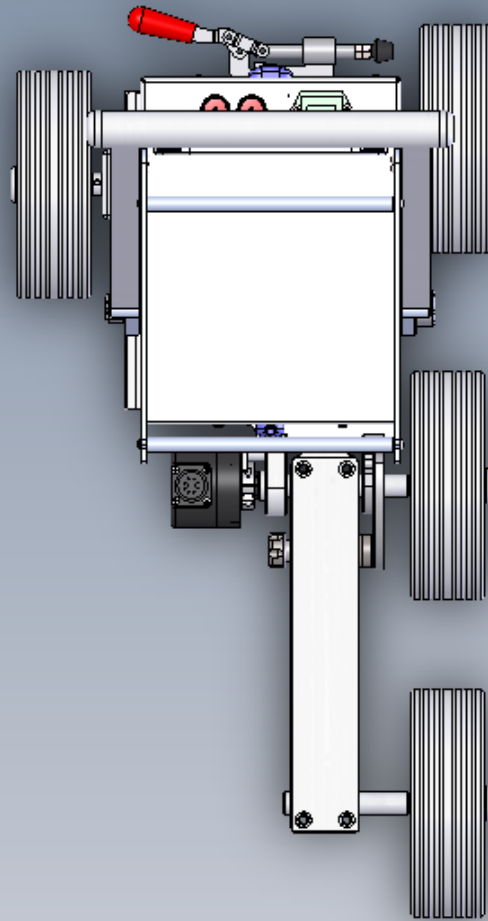
CS8800 (V2-2006)



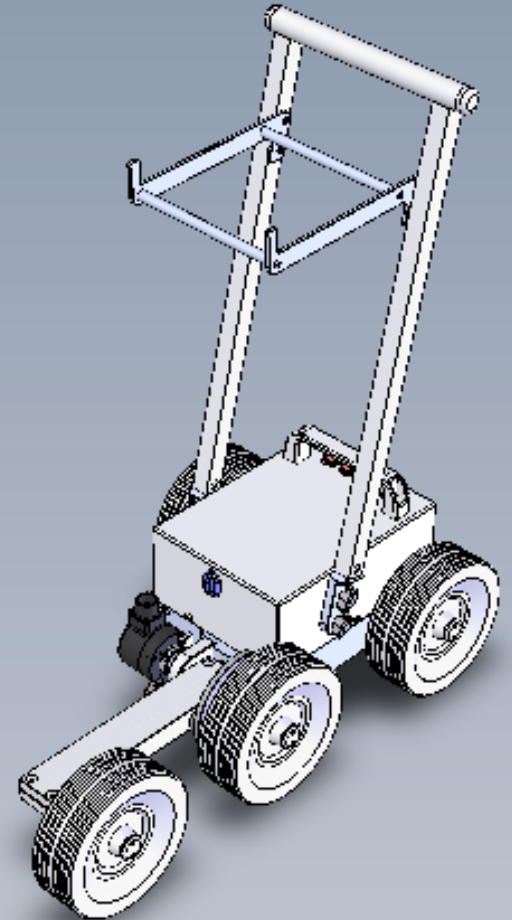
CS8800 DESIGN (V3-2009)



▲ Side ▲



▲ Top ▲

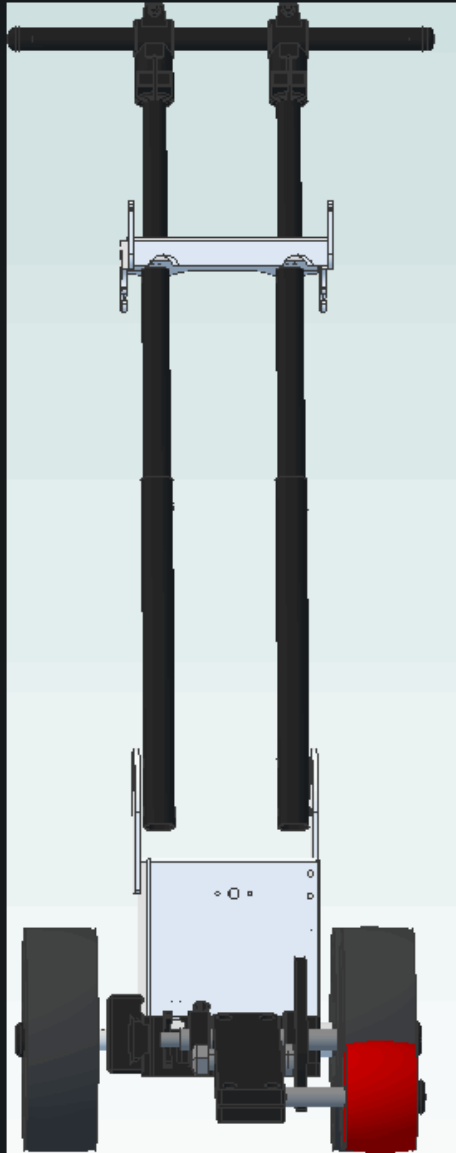


▲ Isometric ▲

CS8800 (V4-2010)



CS8800 (V5 – 2015)



2014-15 Refinements

- 3" Narrower body
- Collapsible handle
- Smaller/Lighter
- CNC machined tires with 11" radius
- Firmware/software overhaul
- Dual axis inclinometer---repositioned in measurement axis
- Laser front-arm
- Temperature compensation (incline & DMI)

Qualities of a Reference Profiler

- Repeatable
 - Shows how elevation trends compare on same surface runs
 - System must pass against itself
- Accurate
 - How the system's collected elevations correlate to an absolute elevation trend
 - Can have output of length (absolute difference) or percentage (cross correlation).
- Waveband Analysis
 - Five separate wavelengths for Accuracy and Repeatability
 - 1-5 ft, 5-25 ft, 25-125 ft and IRI (4-100 ft) wavebands are reviewed
- Operation
 - Speed (nominal and changes during collection)
 - Software Tools and UI

Measurement Principles

- 1 inch or lower sampling interval
- Walking pace (0.5 to 2 feet per second)
- Calibrations vary with temperature
- Collection path is crucial

SSI System Statistics

- Distance encoder receives 10,000 counts per inch
- Front arm elevation data collected every inch
 - Plans to expand to once per millisecond
- Inclinometer samples every millisecond
 - Cross slope and running grade
- Temperature reading six times per minute
- Gyro data currently being collected, but not used

2015 Benchmark vs. Reference Profiler Testing



CS8800--with Laser Front Arm



CS8800-with Wheel Front Arm



MNRoad Benchmark Results

- Easier to collect repeatable and accurate data on consistent, dense, and smooth pavements
- Collected six passes on each surface
 - Dense and Open Graded AC
 - Smooth AC
 - Transverse Tined JPCP
 - Longitudinal Tined JPCP
 - Diamond Ground JPCP
 - Chip Seal
- SSI collected four sets of data with two CS8800 devices

Asphalt (Dense Grade)



Waveband	Repeatability Score		Accuracy Score	
	Required	Achieved	Required	Achieved
IRI	0.98	0.992	0.98	0.975
Long	0.98	0.993	0.98	0.981
Medium	0.98	0.992	0.98	0.960
Short	0.94	0.689	0.94	0.127

Long Dense Graded Results with No Laser FA

Waveband	Repeatability Score		Accuracy Score	
	Required	Achieved	Required	Achieved
IRI	0.98	0.984	0.98	0.945
Long	0.98	0.986	0.98	0.975
Medium	0.98	0.983	0.98	0.957
Short	0.94	0.689	0.94	0.168

Long Dense Graded Results with Laser FA

Asphalt (Pervious/Open Graded)



Open Grade AC Repeatability For No Laser FA

With no DMI correction:

Run 1	Run 2	Cross Correlation by Waveband			
		IRI	Long	Medium	Short
1	2	0.978	0.981	0.981	0.811
1	3	0.991	0.998	0.982	0.798
1	4	0.986	0.988	0.983	0.536
1	5	0.985	0.992	0.969	0.478
1	6	0.973	0.986	0.973	0.579
2	3	0.973	0.981	0.967	0.858
2	4	0.970	0.994	0.971	0.468
2	5	0.968	0.986	0.954	0.490
2	6	0.956	0.965	0.959	0.572
3	4	0.991	0.987	0.984	0.483
3	5	0.984	0.992	0.981	0.486
3	6	0.977	0.987	0.982	0.556
4	5	0.977	0.993	0.966	0.416
4	6	0.972	0.972	0.971	0.448
5	6	0.974	0.976	0.989	0.846
Average		0.977	0.985	0.974	0.588

Open Grade AC Accuracy For No Laser FA

With no DMI correction:

Run	Cross Correlation to Benchmark Profile by Waveband			
	IRI	Long	Medium	Short
1	0.969	0.973	0.950	0.104
2	0.951	0.951	0.936	0.097
3	0.971	0.972	0.957	0.099
4	0.969	0.957	0.948	0.114
5	0.957	0.964	0.950	0.121
6	0.976	0.986	0.958	0.118
Ave.	0.966	0.967	0.950	0.109

CS8800 Performance

CS8800 Walking Profiler 2015 MNRoad Results (Laser Disabled)								
Test Section	Waveband Accuracy				Waveband Repeatability			
	IRI	Long	Medium	Short	IRI	Long	Medium	Short
Dense Grade	0.98	0.98	0.97	0.13	0.99	0.98	0.98	0.69
Smooth Asphalt	0.95	0.97	0.93	0.08	0.97	0.98	0.94	0.42
Chip Seal	0.94	0.96	0.93	0.11	0.95	0.97	0.95	0.77
Porous Asphalt	0.97	0.98	0.96	0.09	0.98	0.99	0.98	0.61
Transverse Tining	0.94	0.98	0.90	0.12	0.97	0.97	0.96	0.44
Diamond Grinding	0.94	0.98	0.93	0.16	0.97	0.99	0.96	0.46
Longitudinal Tining	0.98	0.98	0.97	0.14	0.98	0.98	0.98	0.63
Average	0.96	0.98	0.94	0.12	0.97	0.98	0.96	0.57

2015 vs. 2013



Compare 2015 vs. 2013

CS8800 Walking Profiler 2015 MNRoad Results (Laser Disabled)								
Test Section	Waveband Accuracy				Waveband Repeatability			
	IRI	Long	Medium	Short	IRI	Long	Medium	Short
Dense Grade	0.98	0.98	0.97	0.13	0.99	0.98	0.98	0.69
Smooth Asphalt	0.95	0.97	0.93	0.08	0.97	0.98	0.94	0.42
Chip Seal	0.94	0.96	0.93	0.11	0.95	0.97	0.95	0.77
Porous Asphalt	0.97	0.98	0.96	0.09	0.98	0.99	0.98	0.61
Transverse Tining	0.94	0.98	0.90	0.12	0.97	0.97	0.96	0.44
Diamond Grinding	0.94	0.98	0.93	0.16	0.97	0.99	0.96	0.46
Longitudinal Tining	0.98	0.98	0.97	0.14	0.98	0.98	0.98	0.63
Average	0.96	0.98	0.94	0.12	0.97	0.98	0.96	0.57

CS8800 Walking Profiler 2013 MNRoad Results (Front Arm Disabled)								
Test Section	Waveband Accuracy				Waveband Repeatability			
	IRI	Long	Medium	Short	IRI	Long	Medium	Short
Dense Grade	0.91	0.98	0.87	0.17	0.97	0.97	0.97	0.31
Chip Seal	0.94	0.97	0.93	0.13	0.98	0.99	0.98	0.69
Porous Asphalt	0.94	0.95	0.94	0.11	0.98	0.97	0.98	0.63
Transverse Tining	0.94	0.99	0.94	0.05	0.96	0.99	0.93	0.38
Diamond Grinding	0.92	0.99	0.87	0.08	0.93	0.99	0.88	0.27
Longitudinal Tining	0.89	0.97	0.89	0.33	0.99	0.98	0.99	0.78
Average	0.92	0.97	0.90	0.14	0.97	0.98	0.96	0.51

Inertial Profiler vs. CS8800

MnRoad Longitudinal Tined Section



Inertial Profiler vs. CS8800

MnRoad Longitudinal Tine

SSI High Speed Inertial Accuracy Scores to CS8800 WalkPro				
CS9100 Run #	IRI	Long	Medium	Short
1	0.987	0.968	0.971	0.664
2	0.977	0.978	0.965	0.769
3	0.973	0.967	0.965	0.703
4	0.987	0.96	0.985	0.713
5	0.98	0.963	0.979	0.624
6	0.986	0.957	0.972	0.561
7	0.984	0.955	0.984	0.758
8	0.981	0.966	0.973	0.624
9	0.982	0.966	0.977	0.743
10	0.987	0.982	0.98	0.561
Average	0.982	0.964	0.975	0.684

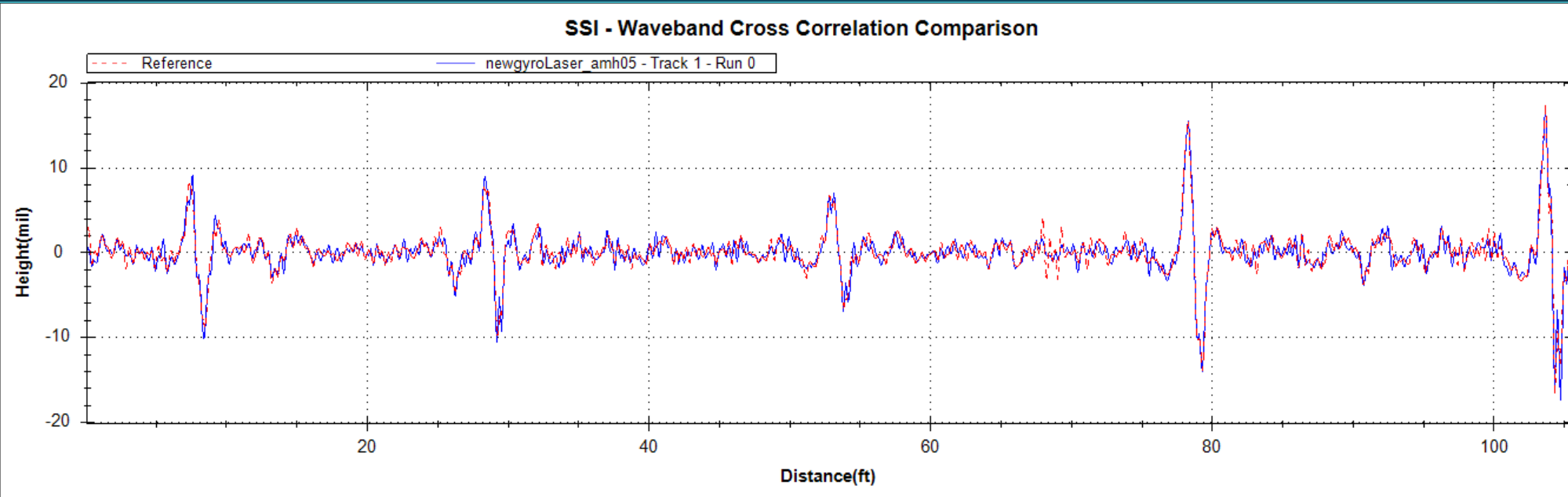
Inertial Profiler vs. Benchmark

Accuracy				
	Waveband			
	IRI	Long	Medium	Short
Requirement	0.90	0.90	0.90	0.80
Dense Graded AC - 25 mph	0.93	0.98	0.91	0.17
Dense Graded AC - 50 mph	0.96	0.98	0.96	0.21
Chip Seal	0.91	0.98	0.92	0.22
Negative Textured AC	0.87	0.94	0.87	0.39
Transverse Tining	0.96	0.97	0.94	0.18
Diamond Grinding	0.98	0.96	0.96	0.41
Longitudinal Tining	0.96	0.94	0.97	0.22
Smooth Asphalt	0.96	0.97	0.94	0.12
Average	0.94	0.97	0.93	0.24
Repeatability				
	Waveband			
	IRI	Long	Medium	Short
Requirement	0.9	0.9	0.9	0.8
Dense Graded AC - 25 mph	0.99	1.00	0.99	0.61
Dense Graded AC - 50 mph	0.98	1.00	0.98	0.65
Chip Seal	0.96	0.99	0.95	0.56
Negative Textured AC	0.97	0.99	0.97	0.60
Transverse Tining	0.97	0.99	0.97	0.64
Diamond Grinding	0.98	0.99	0.99	0.67
Longitudinal Tining	0.98	0.99	0.98	0.47
Smooth Asphalt	0.98	0.99	0.97	0.53
Average	0.98	0.99	0.97	0.59

Short Waveband Challenge

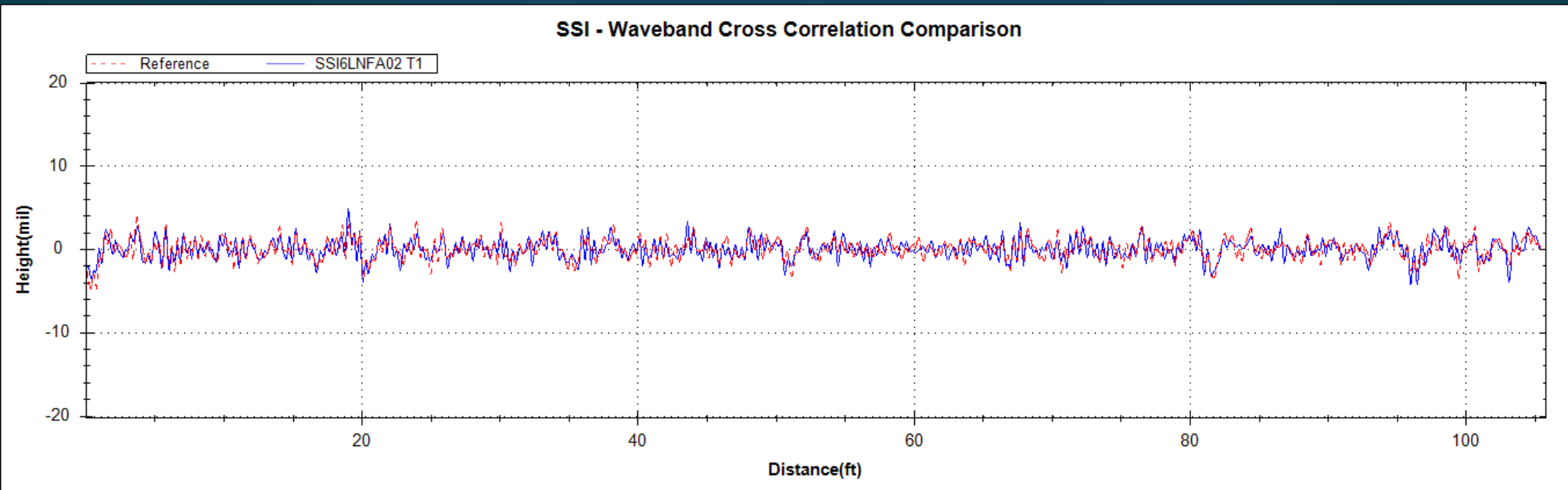
- ▶ How much short waveband content exists?
- ▶ Signal vs. Noise vs. Content
- ▶ Accuracy of Distance Measurement
- ▶ CS8800: merger of FA with incline

Short Waveband Challenge



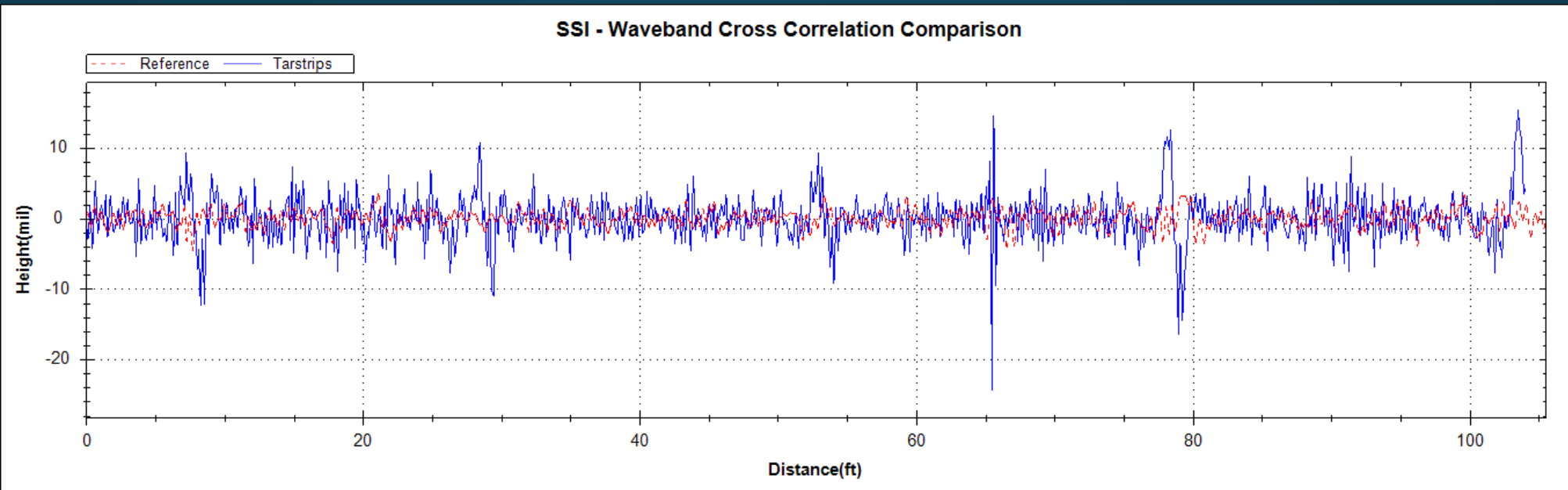
- Crack Seals (tar strips on test track provide well defined short waveband content)
- 94.1% short waveband correlation achieved

Short Waveband Challenge



- MNROAD Longitudinal Tine Section
- How Much Content Exists in the Short Waveband?

Short Waveband Challenge



- MnRoad Longitudinal Tine Section vs. Crack Seal Tar Strips

Goals and Future Adjustments

- Short waveband improved with laser FA
 - Key to passing accuracy and short wavebands
- Inclinator only systems on volatile (OG and chip seal) surfaces performed better than wheel front arm in all but short waveband
- Improve merger of inclinometer & laser/wheel front arm data
- Increase bandwidth to 230400 bits/sec
- Finish gyroscope integration
- Evaluate refinements to distance measurement

Market Options

- Need the instrument to collect all wavelengths
 - Applications may govern requirements
- Inclinator only
- Inclinator and encoder front arm
- Inclinator and laser front arm
- Dual lasers with inclinator
- Pair with total stations for survey elevations
- Equipment also performs ADA compliance and FF/FL testing
- Texture and MPD option with laser front arm

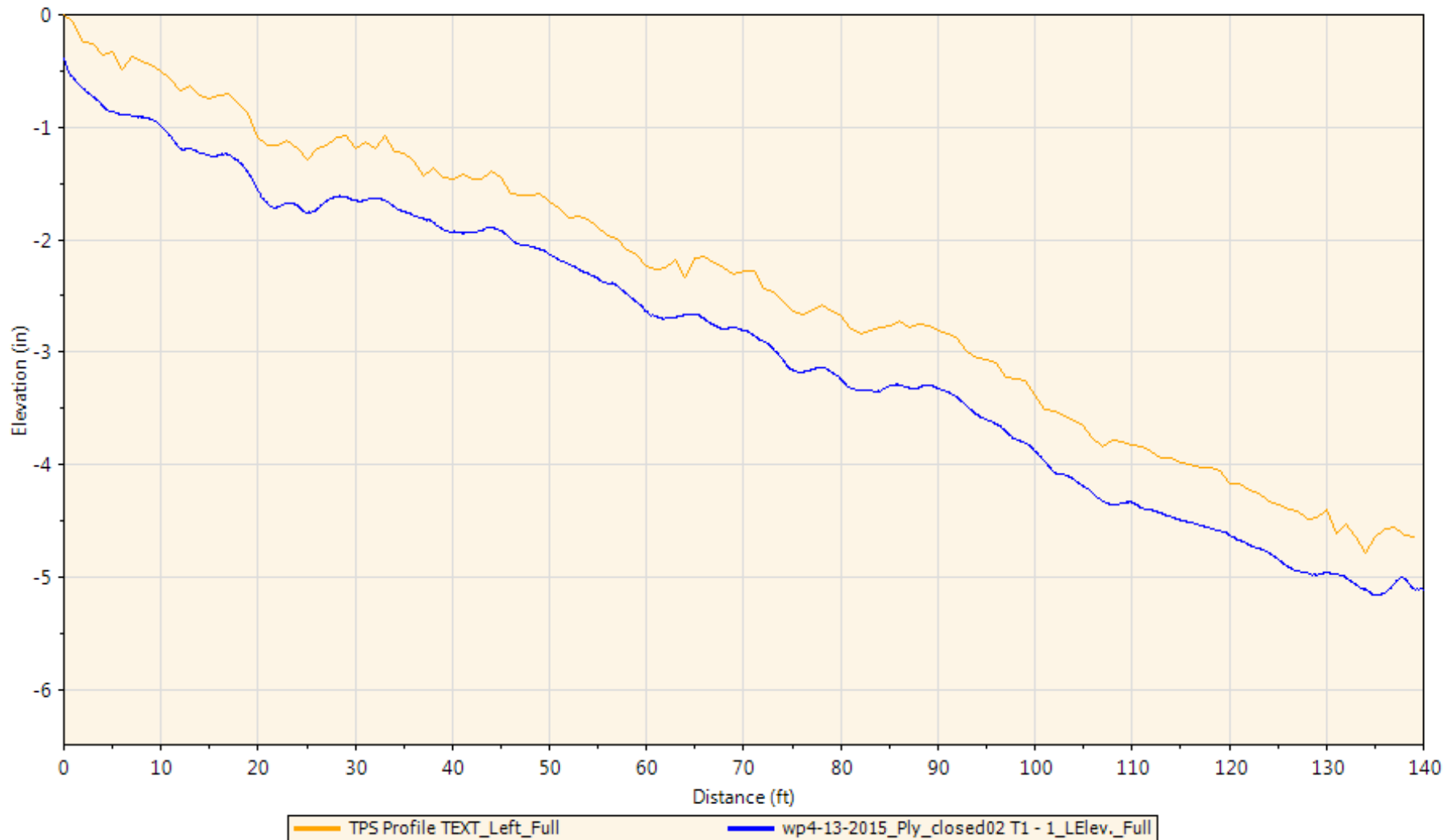
Alternate Solution-3D Survey

Profile/Survey Integration

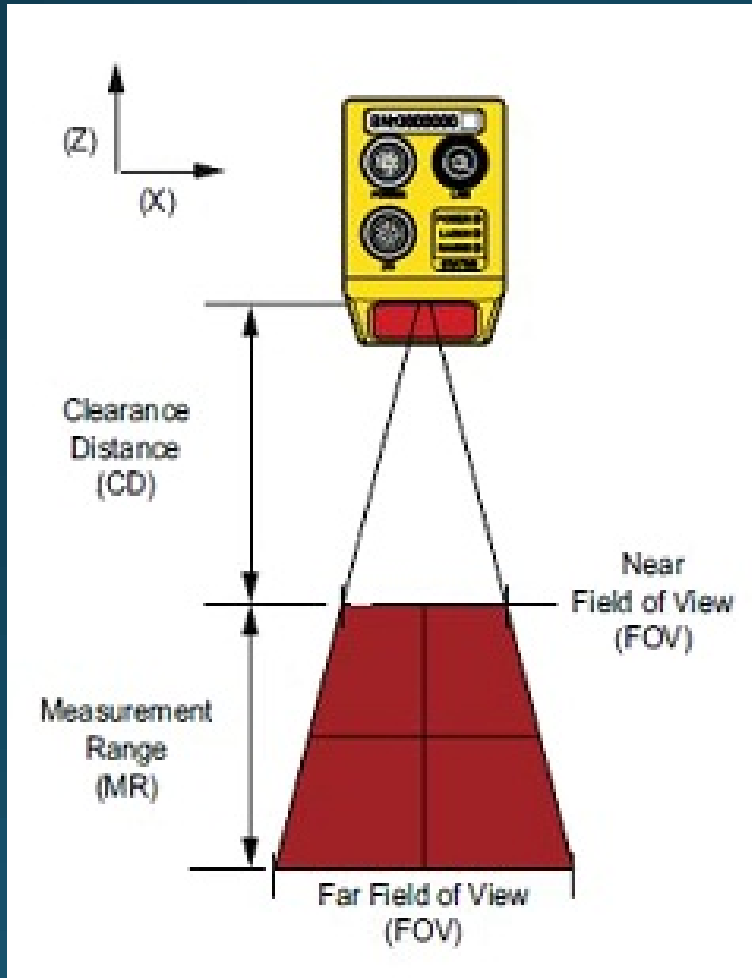
- Dense Profile
- Merge TPS Elevations
- Or Merge RTK GPS
- CAD Output
- Design/Machine Control



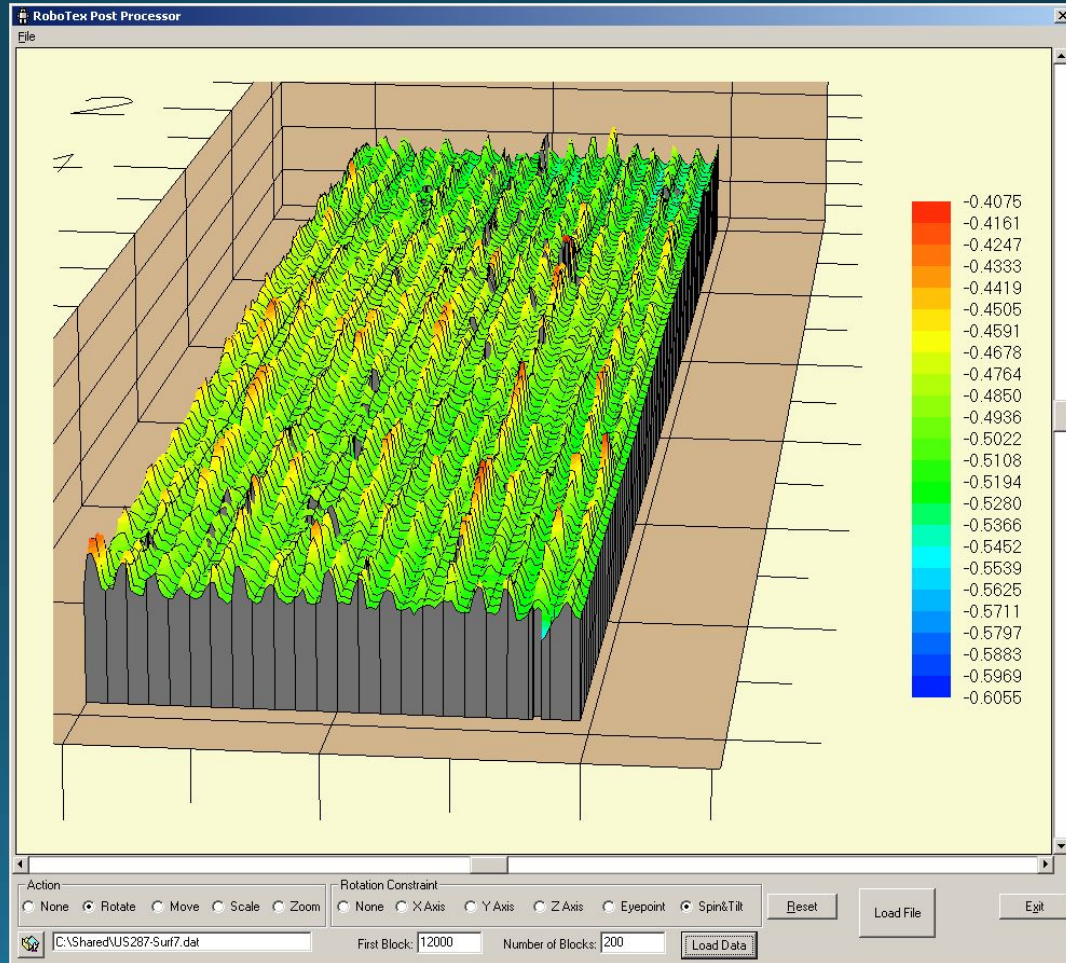
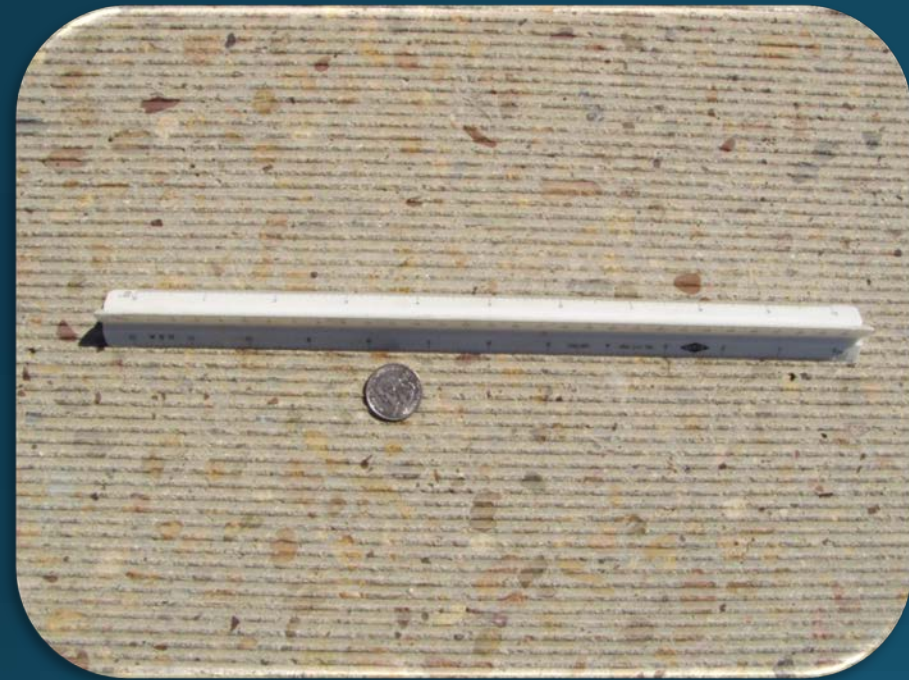
Total Stations vs. SSI CS8800



Texture Option (Gocator)



Texture Scan--Diamond Grind



Solution: ADA Access Criteria

Sidewalk Access Testing

- Running Grade
- Cross-slope
- Evenness (Bumps)
- Sidewalk Rollability
- GPS/GIS Support



Thank You



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